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AUTOMATION AND THE WORKPLACE

SELECTED LABOR, EDUCATION, AND TRAINING ISSUES

A TECHNICAL MEMORANDUM

MARCH 1983

Technical Memoranda are issued by OTA on specific subjects analyzed in recent OTA reports or on projects presently in process at OTA. They are issued at the request of Members of Congress who are engaged in committee legislative actions which are expected to be resolved before OTA completes its assessment.

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Preface

This Technical Memorandum is an interim product of OTA's assessment, "Computerized Factory Automation: Employment, Education, and the Workplace." The assessment is examining the nature and development of automation technologies (such as robotics, computer-aided design and manufacturing, and automated materials handling, storage, and retrieval). The assessment is also evaluating the structure and competitive conduct of industries producing and using programmable automation technologies. Finally, the implications of the production and use of programmable automation for labor and for education and training activities are being examined. The Joint Economic Committee, the Senate Committee on Labor and Human Resources, the Senate Committee on Commerce, Science, and Transportation, and the Subcommittee on Labor Standards of the House Committee on Education and Labor requested the assessment.

This Technical Memorandum discusses procedures for evaluating potential employment change associated with automation, and outlines associated problems. It also provides descriptions of the nature and modes of delivery of education, training, and retraining for persons holding or seeking employment in manufacturing industries. The material draws in part on the products of a July 1982 OTA workshop on labor markets and industrial relations and an August 1982 survey commissioned by OTA of education, training, and retraining activities and trends.

OTA is grateful for the assistance of the assessment advisory panel, the Labor Markets and Industrial Relations Workshop participants, the contractors, and the many others who provided advice and information. However, OTA assumes full responsibility for this technical memorandum, which does not necessarily represent the views of individual members of the advisory panel.

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Chapter 1

Introduction and Concepts

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Chapter 1

Introduction and Concepts

OVERVIEW

Programmable automation technologies are attracting attention as outgrowths of the evolution of computer and communications technologies and as instruments of potentially far-reaching change in the operations, structure, competitiveness, and hiring patterns of many industries, particularly in manufacturing. While popular recognition of programmable automation seems to be confined mostly to one of its forms (robotics), programmable automation comprises other types of hardware, software, and systems.* The family of programmable automation technologies, as applied in manufacturing, is the subject of an Office of Technology Assessment (OTA) study, "Computerized Factory Automation: Employment, Education, and the Workplace," which is scheduled to be completed in late 1983. This technical memorandum, which is an interim product of that assessment, presents a set of concepts and background materials that are fundamental to the analysis of the labor and education and training implications of programmable automation technology.

The OTA assessment is examining the development and production of programmable automation technologies and their use in discrete product fabrication and assembly. It is examining the application of programmable automation to the entire manufacturing process, from design through production. The assessment is concerned in part with the economic and social aspects of the production and use of programmable automation, including:

- impacts on the types and mix of products manufactured,
- the structure and competitive behavior of manufacturing industries,
- the numbers and skill mix of people employed in manufacturing, working conditions in manufacturing jobs, and
- the education and training requirements implied by growth in the production and use of programmable automation.

Although it addresses the potential of programmable automation for the manufacturing sector as a whole, the assessment highlights implications for the transportation equipment, industrial machinery, and electronics industries, where the greatest impacts may occur in the next 10 to 15 years.[1]

Early work on this assessment revealed that analysis of employment change depends critically on methodology, while analysis of instructional requirements demands appreciation of the existing nature of, and delivery system for, education and training. These fundamental issues are the subjects of this technical memorandum. The remainder of this introduction provides a brief review of the evolution of programmable automation and sets out several factors that influence the social and economic consequences of new technologies. The labor chapter (ch. 2) discusses methodology and provides background material useful for evaluating employment and working environment changes. It draws on the products of a workshop held by OTA in July 1982, where questions concerning the analysis of labor markets and industrial relations were debated. The education and training chapter (ch. 3) examines the current status of education and training provided by schools, labor, industry, and others to persons holding or aiming to hold jobs in manufacturing industries. It draws on the results of an August 1982 survey conducted by an OTA contractor.

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*Besides robotics, programmable automation includes computer-aided design (CAD) and manufacturing (CAM), computer-aided process planning (CAPP), automated materials handling (AMH), and automated storage and retrieval systems (AS/RS).

[1] *Exploratory Workshop on the Social Impacts of Robotics—A Background Paper* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, February 1982), OTA-BP-CIT-11.

PROGRAMMABLE AUTOMATION TECHNOLOGIES

Programmable automation may be viewed as the latest development in a long process of enhancing and augmenting human labor with various devices. Throughout history, people have combined human effort and skill directly with the cutting and shaping abilities of tools. With the development of machines, people drew on mechanical and other external sources of power, reducing the amount of human effort, and to some extent skill, needed for production. Automation, in turn, represents an advance over simple machines consisting of a transfer of skills and efforts for operating and controlling equipment and systems from people to machines. Conventional automation has improved production efficiency where automated machinery has been tailored to specific applications and devoted to the production of single products produced in large quantities. Programmable automation, which weds computer and data-communications capabilities to conventional machine abilities, increases the amount of process control possible by machines and makes possible the use of single pieces of equipment and systems for multiple applications. This flexibility may make programmable automation more economical than conventional automation across a range of applications from large volume production to production of small batches of products. Consequently, differences between large-scale, batch, and even custom production techniques may diminish and traditional ways of thinking about manufacturing may ultimately change.

Programmable automation technologies are not new, at least in concept; they have been introduced and refined over the past two to three decades. Many date the launch of programmable automation to the mid-1950's, when numerical control (NC) for machine tools (currently considered as part of computer-aided manufacturing) was developed and commercialized. The intervening years have seen growth in the capabilities and use of NC, the introduction of industrial robotics in the 1960's, and the initial applications of computer technology to manufacturing design, production, planning, and analysis in the 1960's and 1970's. During this period, capabilities and applications for programmable automation have grown, while associated unit costs—at least for the computer aspects—have declined.[2] The technologies and their potential markets appear to have developed sufficiently to lead many manufacturing industry analysts to anticipate substantial growth in the production and use of programmable automation in the 1980's and 1990's. However, current use of programmable automation is limited. For example, while the Robot Institute of America reports that less than 5,000 robots were believed to be in use in the United States in 1981, the National Machine Tool Builders' Association reports that over 2.6 million machine tools were in use in U.S. metalworking industries alone by the late 1970's.[3] [4]

At this time it is possible to identify four attributes of programmable automation, as compared with conventional automation, that may have major ramifications for labor and for education and training:

- capacity for information processing as well as physical work, in connection with such processes as planning, routing, design, fabrication, assembly, monitoring, and diagnosing process problems;
- capacity for quality enhancement, through reliability, precision, and adaptive control of the production process;
- capacity for application to the production of a diverse mix of products, through reprogrammability; and
- capacity for integrating production equipment and systems with each other and with design, analysis, inventory, and other aspects of the manufacturing process.

These attributes will influence: 1) the types and the range of human skills and other abilities that can be replaced by machines, 2) the types of new applications within which both men and machines can be combined, 3) the types of skills required to produce programmable automation, 4) the types of products (existing and new) for which programmable automation may be used, 5) the costs of producing given quantities of different products, and 6) the organization and management of the manufacturing process. Consequently, they may give rise to changes in the numbers and types of people employed, and therefore changes in requirements for education, training, and retraining. Distinctive attributes of programmable automation will also influence the working environment of people employed in manufacturing. How much, and in what ways employment patterns and working environments change will depend on how automated equipment and systems are designed and implemented.

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[2] "SME Golden Anniversary Issue, 1932-1982: A Review of Manufacturing and the Society Which Guides Its Progress," *Manufacturing Engineering*, January 1982.

[3] *Worldwide Robotics Survey and Directory* (Dearborn, Mich.: Robot Institute of America, 1982).

[4] *Economic Handbook of the Machine Tool Industry* (McLean, Va.: National Machine Tool Builders Association, 1982-83).

Conventional automation and other types of manufacturing technologies have traditionally affected—both positively and negatively—the employment and working environment of manual workers. Because of its capacities for performing information processing work and for integrating the manufacturing process, programmable automation may also have significant impact on other types of workers, the so-called white- and gray-collar workers, including managers.

DIMENSIONS OF TECHNOLOGICAL CHANGE

It is possible to relate the emerging capabilities of programmable automation technologies to changes in employment, and therefore education and training requirements, in the abstract. However, the effects of programmable automation on labor overall, as well as the experiences of specific groups of people, depend on how programmable automation technologies are implemented. The development and implementation of programmable automation, or other new technologies, can be appraised according to three factors: 1) the rate of technological change, 2) the nature of the change, and 3) the pattern of technological diffusion associated with programmable automation. These factors, which reflect a combination of technological and industrial/economic factors, are central to assessments of the social and economic impacts of new technology. They are reviewed briefly below.

Rate of Technological Change

There are two components to the rate of technological change, the rate at which new technologies are created and the rate at which they are adopted by users. For appraising the impacts of technology on employment and related education and training needs, the rate of adoption is key; it determines whether changes in requirements for different types of labor affect primarily existing or future/prospective employees. Although new technologies may be created at varying rates, the conventional view among economists is that the use of new technologies spreads relatively slowly. It is commonly assumed that firms adopt new technology in a rational fashion, meaning that they strive to use the most affordable processes to avoid the costs of prematurely scrapping facilities and to adapt technologies to their individual needs. This view implies that, since firms typically do not adopt each technological advance as soon as it is developed and since firms experience some normal level of employee turnover, employees are not (repeatedly) subject to catastrophic displacement. A more elaborate presentation of this view and a discussion of supporting research can be found in a paper by L. Jacobson and R. Levy, appendix C.

Although the notion that there is a lag between the introduction of a new technology and its widespread use is commonly recognized, there is disagreement as to whether recent innovations based on microelectronics technology have or will continue to spread as slowly as previous ones. For example, innovation and associated employment change in the printing industry have proceeded quicker than the conventional view might lead one to expect.

> In West Germany, for example, employment among printers dropped by 21.3 percent between 1970 and 1977, while productivity per hour rose by 43.5 percent . . . .[5]

There is also evidence that the use of computers has spread relatively rapidly, a phenomenon that has prompted many scientists and engineers to take steps to refine their skills. A discussion of technological diffusion and its impacts on scientists and engineers is found in a paper by W. Cooke, appendix C. Additional material on engineering education is presented in chapter 3 of this technical memorandum.

A central question for an analysis of the social and economic impacts of programmable automation is whether programmable automation is likely to spread especially rapidly among firms and industries, and why. Answering that question requires appraising the influence of the international nature of markets producing and using programmable automation and the influence of cyclical and structural change in the U.S. economy on the rates of adoption and production of programmable automation in the United States.

Nature of Technological Change

The way in which technological change affects employment and instructional requirements depends on the nature of the technology. The aspects of the technology that are relevant to an examination of labor impacts fall into three categories:

1. process v. product technology,
2. embodied v. disembodied technology, and
3. capital intensity of technology.

Process technologies are technologies of production, while product technologies pertain to the attributes of a finished product. Programmable automation, which comprises a set of goods and services used by businesses to make other products, has elements of both, but is primarily regarded as process technology.

The product-process distinction is important because, historically, process changes have been more likely to affect employment adversely than have product changes. New products (such as programmable automation equipment and systems) create new markets and new sources of employment (although net employment growth depends on whether—and when—new products replace older ones). New processes, however, are often adopted because they are considered efficient, using fewer resources than older processes to yield a product of given quality.* If the conserved resource is labor, a company adopting a more efficient process will need fewer employees for a fixed output level. If the company faces a mature market for its end product (i.e., sales volume is not likely to grow significantly), overall employment will fall, but, if the company faces a growing market, it might experience stable or growing employment. Also, some new processes may be adopted to improve product quality without necessarily diminishing company employment. Discussions of programmable automation in the trade and business press typically note its potential for both efficiency and quality enhancement. These discussions, which separate quality gains from cost reductions, recognize that process improvements may facilitate output growth but do not assure that companies can sell larger volumes of output.

Embodied technologies are associated with physical entities such as pieces of equipment. For example, mechanical adding machines and electronic calculators embody different technologies to perform the same functions. Disembodied (sometimes called soft) technologies constitute ways of organizing and managing production that are not locked into tangible items. An example is the just-in-time system of inventory management, wherein suppliers deliver materials for virtually immediate use (rather than interim storage). The contrast between embodied and disembodied technologies is important for appraisal of programmable automation because the spread and the ultimate utility of programmable automation is linked to associated changes in the organization of production and the structure of companies and industries.

In evaluating embodied technologies used in manufacturing and elsewhere, it is important to recognize that disembodied technologies can often complement or even substitute for them. For this reason, comparing counts of different types of equipment (e.g., robots) used by different countries may be misleading. As comparisons of automobile production in the United States and abroad reveal, it is possible to produce the same product using equipment and systems that differ in sophistication under different principles of organization and management. Also, because embodied and disembodied technologies are combined in production, simple attributions of employment or working environment variations to changes in equipment and systems are hazardous; they ignore the role of management, organization of production, and other "soft" factors.

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[5] Colin Norman, *Microelectronics at Work: Productivity and Jobs in the World Economy*, Worldwatch Paper 39, October 1980.

*Sometimes this characteristic is referred to as productivity improvement, since productivity refers to the amount of output derived per unit of input to production.

Capital intensity refers to the amount of investment in plant and equipment needed to produce a given level of capacity, relative to the amount of other inputs, such as labor. A capital-using change in technology is defined to be one that requires more investment to produce a unit of product than the original technology; a capital-saving change, one that requires less investment; and a capital-neutral change, one that requires the same investment per unit of product.

Generalizations about how programmable automation may affect capital intensity in different manufacturing applications are difficult to make at this time because of limited experience with the technologies and uncertainty about the evolution of the technologies and their markets. However, an understanding of the capital intensity aspects of programmable automation is important for understanding the long-term employment and wage impacts of programmable automation. In brief, capital intensity affects the flexibility employers have for accommodating different employment and wage levels, given company levels of sales volume and of output per worker.* The ramifications of varying levels of capital intensity are examined in a paper by E. Appelbaum, appendix C.

Pattern of Technology Diffusion

The impacts of programmable automation technologies will depend on where they are used as well as when. New technologies may spread within industries among all firms, among firms in only certain industry segments, or among large or leading firms only. They may be used in isolated industries, interdependent industries, and/or in industries in different sectors of the economy. The impact of programmable automation technologies on employment (and therefore on instructional requirements) in the United States will depend, in particular, on global trends in the production and use of programmable automation, since the markets for automation and for many products made with it are international.

Preliminary observations presented by industry and labor representatives and technology analysts at the 1981 OTA Exploratory Workshop on the Social Impacts of Robotics and elsewhere indicate that programmable automation may eventually be diffused more broadly than conventional automation.[6] While conventional automation has been applied primarily in large-volume or mass-production manufacturing industries, programmable automation offers potential value to use in smaller volume, batch manufacturing applications, which are the majority of manufacturing applications.[7] Whereas conventional automation is devoted to production of single products, programmable automation equipment and systems can be adapted, through reprograming, for production of multiple products, each of which may be desired in limited quantities. Since production equipment and systems themselves are often manufactured in small-quantity batches, their manufacture may be automated.

Finally, equipment and systems similar (and in some cases identical) to those used for programmable automation in manufacturing are being adopted in nonmanufacturing settings, with multiple impacts on employment opportunities. A possible consequence of the spread of office automation, for example, is a decline in the growth rate of clerical employment. On the other hand, large investments in office automation equipment and systems imply potential employment gains in manufacturing industries supplying office automation, although who benefits from such employment gains depends on the extent to which office automation equipment is imported. The implications of the pattern of technology diffusion for employment in different sectors of the economy are discussed in a paper by E. Appelbaum, appendix C.

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*Capital intensity may also affect the distribution of wealth generated through production—a shift to capital-using technologies may, for example, be associated with growth in profits (return on capital) relative to wages. Changes in the distribution of wealth in turn may affect employment and wage levels because those realizing income as profits may spend and invest in different markets than those realizing income as wages.

[6] *Exploratory Workshop on the Social Impacts of Robotics—A Background Paper*, op. cit.

[7] Ibid.

Chapter 2

Labor Markets and Working Environment

Chapter 2

Labor Markets and Working Environment

INTRODUCTION

The use of computers in manufacturing has aroused concern since the late 1950's and early 1960's, when awareness of the potential of computer technology began to emerge and when applications of more conventional automated manufacturing were accelerating. During that period public interest in the social ramifications of automation and computers was greater in Europe than in the United States. However, official U.S. concern led to the formation in 1965 of a special Federal study commission, the National Commission on Technology, Automation, and Economic Progress, charged with the tasks of: 1) assessing the effects, role, and pace of technological change; 2) describing changes in employment demands and working conditions associated with technological change; 3) defining "unmet community and human needs" that technology can help to meet; and 4) identifying policy options for implementing new technologies. After meeting for a year, the Commission issued a report that foreshadows contemporary discussions of job displacement, changing working conditions, and instructional needs.

From the 1950's through today, labor-related concerns associated with automation and computers have tended to fall into three not-wholly-distinct categories: 1) labor markets or employment, 2) working environment (job content and occupational safety and health), and 3) industrial or labor-management relations. Of these three categories, labor market issues have been most salient in popular (and political) discussions of automation, because employment is widely seen as reflecting the economic vitality of a country or region. By contrast, working environment issues may be more subtle and more likely to be appreciated by those groups of people in direct contact with specific working environments. Finally, industrial relations both influence and are influenced by changes in labor markets and working environments that are associated with new technology and other factors.

In order to analyze the labor market implications of programmable automation, it is necessary to be able to measure and forecast the degree and types of changes in employment that may accompany the spread of this technology. The variety of claims as to the eventual employment impacts of programmable automation that are being publicized by the media suggests that such evaluations are straightforward. However, there appears to be no accepted methodology for making such employment forecasts reliably, a problem that was emphasized in debates among participants of the OTA Labor Markets and Industrial Relations Workshop. This technical memorandum points out some of the shortcomings of many publicized forecasts and some of the requirements for satisfactory forecasts.

POTENTIAL FOR OCCUPATIONAL CHANGE: AN OVERVIEW

A first step in measuring or forecasting how programmable automation or other new technologies may affect employment—by occupation and industry—is to assess: 1) how programmable automation affects the activities performed by people working in user industries and occupations, and 2) what types of activities may be performed by people engaged in producing automated equipment and systems. Unfortunately, there are few empirical data describing relevant activities. Moreover, what data may exist (e.g., in case studies) may have little general value because early programmable automation applications have been limited in number compared to applications of other types of equipment and systems, and they have been tailored to individual company needs. Early applications also are likely to be different from later applications involving more sophisticated equipment and systems, especially since future applications are expected to feature greater computer integration of production and other company activities.

At this time it appears that the range of activities undertaken by manufacturing firms and vulnerable to change in connection with programmable automation is not limited to the fabrication and assembly of products. Employment that may be directly affected by the production and use of programmable automation is associated with a wide range of activities, including research and development; the design, fabrication, assembly, distribution, and servicing of products; and management.

Production Activities.—The types of new activities associated with production of programmable automation, as compared with production of conventional factory equipment, are those that pertain to its computerization aspects, namely the development, distribution, and/or adaptation of computer hardware and software. Computerization, or more broadly a shift to microelectronics from mechanical or electromechanical components, may also alter other activities associated with production of programmable automation. For example, the use of microelectronic components affects fabrication and assembly techniques, in part because individual microelectronic components can often do the work of multiple mechanical ones.[1] Finally, like the production of conventional equipment, production of programmable automation also entails applications engineering, technical support, installation, sales, and clerical activities.

Use Activities.—Activities associated with the use of programmable automation are broadly similar to those associated with the production of programmable automation, since both production and use of programmable automation are manufacturing endeavors. Nevertheless, variation among user industries (including users who also produce programmable automation) by size and by nature of product will determine the specific types of tasks and occupations affected among users. The types of tasks that may be created with the use of programmable automation also pertain to computerization (e.g., programing, maintenance of electronic equipment, and data base management). The types of tasks that may be eliminated are those tasks sensitive to the internalization of information flows (e.g., for certain clerical operating and supervisory tasks), or to the replacement of physical labor (e.g., for welding, assembling, materials handling, and drafting).

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[1] Roy Rothwell and Walter Zegveld, *Technical Change and Employment* (New York: St. Martin's Press, 1979).

OCCUPATIONAL CHANGE FORECASTING

Historically, attempts to forecast detailed changes in occupational employment have met with limited success. As the Bureau of Labor Statistics (BLS) has noted in evaluating its own forecasts, it is easier to predict directions of change for broad categories of employees than magnitudes of change for relatively specific groups. This situation is unfortunate, since the more detailed the occupational differentiation, the more precise may be the evaluation of employment variation among occupations and industries and therefore the identification of people who may benefit or be harmed by technological change.[2]

The occupations of people who may be directly affected by the spread of programmable automation include professional specialty; executive, administrative, and managerial; technicians and related support; machine operators, assemblers, and inspectors; precision production, craft, and repair; and handlers, equipment cleaners, helpers, and laborers. Table 1 contains the full current and prior lists of major census occupational groups. While this set of categories can be used to describe the occupational mix of any industry and the labor force as a whole, it is too broad to describe more than gross shifts in oc-

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[2] Max L. Carey and Kevin Kasunic, "Evaluating the 1980 Projections of Occupational Employment," *Monthly Labor Review*, July 1982.

Note that in practice, very detailed occupational analyses may be less accurate than more aggregated analyses because of nonsampling errors in occupational title classification and analysis. See Harvey Goldstein, "Occupational Employment Projections for Labor Market Areas: An Analysis of Alternative Approaches" (Washington D.C.: U.S. Department of Labor, 1981), R&D Monograph 80.

Table 1.—A Comparison of 1980 and 1970 Decennial Census Occupational Categories

1980	1970
Broadest groupings	
Managerial and professional specialty	White-collar
Technical, sales, and administrative support	Blue-collar
Service	Service
Precision production, craft, and repair	Farm
Operators, fabricators, and laborers	
Farming, forestry, and fishing	
Major occupational groups	
Executive, administrative, and managerial	Professional and technical
Professional specialty	Managers and administrators, except farm
Technicians and related support	Sales
Sales	Clerical
Administrative support, including clerical	Craft and kindred
Private household	Operatives, except transport
Protective service	Nonfarm laborers
Service, except private household and protective service	Private household
Precision production, craft, and repair	Other service workers
Machine operators, assemblers, and inspectors	Farmers and farm managers
Transportation and material moving	Farm laborers and supervisors
Handlers, equipment cleaners, helpers, and laborers	
Farming, forestry, and fishing	

SOURCE: John E. Bregger, "Labor Force Data From CPS to Undergo Revision in January 1983," *Monthly Labor Review*, November 1982.

cupational proportions. Within each category, hundreds of occupations can be differentiated. Aggregating occupational categories may result in uncertainty about future change in such detailed occupations as "robot technician," where the specific designation falls within a broader category, such as science and engineering technicians. Another cost of aggregation is generality—the average pattern of change within an industry may not correspond to actual changes experienced by individual companies or people, in part because individual companies vary in their use of employees with very specific skills, as well as in their use of production technologies. However, even a detailed occupational breakdown may mask changes in job content that may arise with new technology.

Most analyses of employment change use aggregated occupational descriptions because collection and manipulation of more detailed occupational data are costly, and because the most detailed descriptions fall easily out of date. Many experts believe that analysts have been handicapped by the kinds of data available. For example, the most recent edition of the *Dictionary of Occupational Titles* (DOT), which describes 200,000 occupations, was published 6 years ago in 1977 (the previous edition was published in 1965). The DOT does not contain an entry for "robot technician," and the most similar entry, "automated equipment engineer technician," refers to an individual who works with machinery producing items from paper or cardboard stock (as opposed to metal, plastic, or other materials with which robots or other forms of programmable automation might be used).

How can the effects of programmable automation on employment levels and distribution among occupations be gaged? Already, there are many estimates of the overall and occupational employment impacts of programmable automation appearing in the trade, popular, and business presses. Examples include the following:

> Automotive industry sources say the general formula is that 1.7 jobs are lost for every robot introduced.[3]

> "Automation will cause a 20 to 25 percent decline in the factory work force over the next decade," says Thomas G. Gunn, managing director of Arthur D. Little's computer integrated manufacturing group. An internal study done by GE shows that it is now technologically possible for the company to replace half of its 37,000 assem-

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[3] Joyce Price, "With Robots On the Way, GM Workers Worry," *The* (Baltimore) *News American*, Sept. 27, 1982.

> bly workers with machines. Company officials are quick to point out that they have no plans to do that and where GE is automating existing plants—at Erie, for instance—it is retraining the displaced workers. Sometimes extensive automation also creates new jobs even as it destroys others. The new automated parts factory in Florence, Ky., for example, will allow Yamazaki to expand production at its manned machine-tool assembly plant nearby; 100 workers will be hired to fill the new jobs.[4]

> Experts estimate that on the order of 45 million existing jobs—45 percent of all jobs, since there are about 100 million people at work—could be affected by factory and office automation. Much of the impact will occur before the year 2000 . . . The United Auto Workers, one of few unions that tries to anticipate automation expects its auto industry membership to drop to 800,000 from 1 million between 1978 and 1990, even assuming a 1.8 percent annual increase in domestic auto sales . . . . Harvey L. Poppel, a senior vice-president with Booz, Allen & Hamilton, Inc., estimates that 38 million of more than 50 million existing white-collar jobs eventually may be affected by automation. Paul A. Strassmann, vice-president of strategic planning for Xerox Corp.'s Information Products Group, predicts that 20 million to 30 million of these jobs will be affected by 1990.[5]

> Forecasting is, at its best, imprecise. However, the impact of robotics will definitely mean the elimination of some blue-collar jobs and the creation of jobs that didn't exist as recently as 10 years ago. It's estimated that there are currently 10,000 workers involved in robotics in some form or another throughout the world. That includes everyone from assembly line workers to designers, engineers, company presidents, clerical help, maintenance people and all of the support necessary for a young, developing industry.[6]

The above sources have derived their estimates through various means. The estimation procedures used appear to fall into two categories: "engineering" and "economic." Both categories derive labor requirements from other phenomena: equipment in the former category, and demand for finished products in the latter. These procedures are reviewed below to illustrate how limited current understanding and modeling of programmable automation employment impacts really are.

Engineering Estimates

Engineering estimate is the term used in this report to refer to an estimate based more or less exclusively on technical aspects of technological change. Although engineering analyses may be used to support economic analyses of employment change, they are frequently used on their own. Most of the employment (or, in particular, unemployment) estimates cited in popular discussions of programmable automation seem to be of this type.

Engineering estimates are made by describing the capabilities (for physical and mental work) of new automation technologies, projecting capability improvement over time, comparing the capabilities to tasks performed by humans, relating human tasks to different occupations, and deriving the number of jobs, by occupation, that could be assumed by new and future improved types of equipment. This is done by comparing guesses as to the percentages of work that could be transferred to programmable automation with counts of the numbers of people currently doing that work. For example, the employment impact of a welding robot might be estimated by identifying the types of welds the robot can perform, measuring the number of welds the robot can perform in a given period of time, and calculating the number of "jobs" that might be displaced by comparing the number of robots needed to achieve a given volume of welds with the number of human welders who could achieve the same volume of welds, given contemporary hiring patterns. Projected improvements in robot welding, or other changes in the basic assumptions can be accommodated by modifying the calculations.

Similar calculations are used to derive the employment requirements for producing the supply of robots necessary to achieve a given level of displacement—estimate the type of tasks required to produce robots, the number of tasks of each type required per robot, the allocation of robot-production tasks between humans and equipment, and combine with the number of robots desired in a given period to forecast producer employment requirements.

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[4] "The Factory of the Future," *Business Week*, Sept. 6, 1982.
[5] "Changing 45 Million Jobs," *Business Week*, Aug. 3, 1981.
[6] Joel Weber, "Can Robots Do a Better Job?" *D&B Reports*, January/February 1980.

Shortcomings of Engineering Estimates

The engineering approach is easily understood, adaptable to different assumptions, and useful as a first step in estimating the potential employment impacts of programmable automation. However, it has many limitations—in its application, if not its concept—which are largely functions of the narrowness of the technological and/or economic assumptions chosen. Shortcomings of engineering estimates may include some or all of the following:

- These estimates are easily confounded by errors in projecting future technological capabilities. Although providing a range of assumptions may improve the usefulness of the estimates, there remains a problem of inability to foresee all possible developments, especially in new technologies.
- Both the development and the analysis of automation technologies (conventional and also programmable) often rely heavily on point-by-point comparisons of electronic and mechanical capabilities with human capabilities, an orientation that lends itself to calculations of how and where automation equipment and systems may replace or substitute for human activities. See table 2. However, this orientation fails to capture the potential for programmable automation either to perform jobs in ways other than simulation of human behavior, or to perform jobs that are poorly done or not done at all by humans because of human limitations. This failure may lead to overestimation or underestimation of job displacement.
- Engineering estimates may be misleading because they tend to yield a "technically" ideal mix of humans and equipment, while the actual mix may reflect complex management and implementation considerations that are independent of the capabilities of specific equipment or systems. For example, managers may be motivated out of risk aversion to provide redundant capabilities in the form of "extra" workers (or overskilled workers) to provide manual performance backup or monitoring services, at least in the short term when programmable automation is relatively unfamiliar. Varying assumptions about the mix of humans and equipment would ease this problem.
- Engineering estimates are frequently based on current or recent labor force characteristics. This practice assumes that users will buy and use programmable automation to serve relatively constant production needs, and that workers will seek different jobs at constant rates. However, the job displacement and creation consequences of programmable automation will depend not only on how programmable automation affects the number and type of tasks per worker, but also on how sales volume and the mix of products—which determine the total number of tasks done at all—change. These quantities may vary in response to factors other than technological change, such as shifts in consumer tastes. In addition, the employment consequences of programmable automation will depend on the numbers and types of people willing and able to work at different types of jobs, which also may vary independently of technology.

Engineering analyses are useful for identifying the types of people (excluding, perhaps, managers) who may be affected by programmable automation. As currently used, they are often too simplistic to provide realistic estimates of industry or economywide employment change. The chief problem with available engineering estimates of national employment impacts seems to be a lack of consideration for variations in economic conditions, trade patterns, and labor supply, although these factors probably could be accommodated by engineering analyses. Nevertheless, the engineering approach provides a framework that can be used to evaluate the employment consequences of alternative strategies for implementing programmable automation, and a mechanism for evaluating specific variations in production processes.

Table 2.—Comparison of Robot v. Human Skills and Characteristics

Robot[a]	Human
A. Action and manipulation	
1. Manipulation abilities	
a. One or more arms. Automatic hand change is possible.	a. Two arms—two legs—multipurpose hands.
b. Incremental usefulness per each additional arm can be designed to be relatively higher than in humans.	b. Two hands cannot operate independently.
c. Requires the same amount of feedback throughout operation.	c. Feedback requirements (type and quantity) change with practice—initially relatively higher than robot; visual feedback dominates other sources of feedback.
d. Movement time related to distance moved by speed, acceleration and deceleration, and will increase with higher accuracy requirements.	d. Movement time and accuracy governed by Fitts law. High precision movements may interfere with calculation processes.
• • •	
B. Brain and control	
1. Computational capability	
a. Fast, e.g., up to 10 K bits/sec for a small minicomputer control.	a. Slow—5 bits/sec.
b. Not affected by meaning and connotation of signals.	b. Affected by meaning and connotation of signals.
c. No valuation of quality of information unless provided by program.	c. Evaluates reliability of information.
d. Error detection depends on program.	d. Good error detection/correction at cost of redundancy.
e. Very good computational and algorithmic capability by computer.	e. Heuristic rather than algorithmic.
f. Negligible time lag.	f. Time lags increased, 1 to 3 sec.
g. Ability to accept information is very high, limited only by the channel rate.	g. Limited ability to accept information (10 to 20 bits/sec).
h. Good ability to select and execute responses.	h. Very limited response selection/execution (1/sec); responses may be "grouped" with practice.
i. No compatibility limitation.	i. Subject to various compatibility effects (RR, SR, SS).
j. If programmable—not difficult to reprogram.	j. Difficult to reprogram.
k. Random program selection can be provided.	k. Various sequence/transfer effects.
l. Command repertoire limited by computer compiler or control scheme.	l. Command repertoire limited by experience and training.
2. Memory	
a. Memory capacity from 20 commands to 2,000 commands, and can be extended by secondary memory such as cassettes.	a. No indication of capacity limitation.
b. Memory partitioning can be used to improve efficiency.	b. Not applicable.
c. Can forget completely but only on command.	c. Directed forgetting very limited.
d. "Skills" must be specified in programs.	d. Memory contains basic skills accumulated by experience.
	e. Slow storage access/retrieval.
	f. Very limited working register = 5 items.
3. Intelligence	
a. No judgment ability of unanticipated events.	a. Can use judgment to deal with unpredicted problems.
b. Decisionmaking limited by computer program.	b. Can anticipate problems.
• • •	
E. Miscellaneous factors	
• • •	
3. Training	
a. Requires training by teaching and programing by an experienced human.	a. Requires human teacher.
b. Training doesn't have to be individualized.	b. Usually individualized is best.
c. No need to retrain once the program taught is correct.	c. Retraining often needed due to forgetting.
d. Immediate transfer of skills ("zeroing") can be provided.	d. Zeroing usually not possible.
	e. Very costly.
	f. Not everyone can be taught.
4. Social and psychological needs None	a. Emotional sensitivity to task structure—simplified/enriched; whole/part.
	b. Social value effects.
5. Individual differences Only if designed to be different.	100 to 150 percent variation may be expected.

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[a] Robot parameter values are cited from currently available industrial robot literature.

SOURCE: Nof, Knight, and Salvendy, "Effective Utilization of Industrial Robots—A Job and Skills Analysis Approach," *AIIE Transactions*, vol. 12, No. 3, September 1980.

Economic Estimates

Economic estimates is the term that will be used in this technical memorandum to refer to projections based on macroeconomic models. Economic estimates are better than engineering estimates for projecting aggregate changes in employment patterns because they are inherently more comprehensive. On the other hand, economic estimates may not be practical or useful for gaging possible employment change at the company level because they tend to be highly aggregated.

Economic estimates are made by explicitly evaluating several factors, in addition to technology, that impinge on employment demands. For example, prices and production levels of goods and services are typically considered, taking into account, in turn, the forces that affect these factors, such as international trade and projected shifts in the relative strengths of different sectors of the economy. Economic estimates place substantial emphasis on descriptions of employers in terms of different sectors of the economy and different industries within sectors. They rely on engineering analyses for descriptions of alternative effects of technologies on industry requirements for such production inputs as labor (by occupation), equipment, and materials.

Economic estimates of employment change are made using mathematical models of production functions, which describe how different inputs to production are combined to yield a given level of output. Some models pertain to single industries, while other, more elaborate models also take into account the interactions among industries. The most detailed economic estimates come from large-scale models, in particular those based on so-called input-output (I-O) models, which encompass entire (regional, national, or global) economies. Technologies are defined in I-O models as the structure—number, type, and proportions—of inputs associated with the production of a unit of output of a given product.

The employment forecasts (total and by occupation) of the BLS draw on large-scale economic modeling. They are generated with an I-O model of the U.S. economy in combination with other models that forecast change in the labor force and in the level and pattern of economic activity. Also included are descriptions of staffing patterns (the mix by proportion of different types of workers) for each industry included, obtained from periodic surveys. Since the BLS estimates are widely used, and since the procedures are substantially similar to procedures used by others who forecast with large-scale economic models (indeed, other models often use the same data), a description of the outlines of BLS forecasting procedures can serve as a description of economic employment forecasting procedures in general (although individual models and procedures do differ in their details).*

Figure 1 shows the different computational elements that contribute to BLS forecasts. The first set of procedures is the projection of labor force characteristics. The second set of procedures is the projection of overall economic activity and resulting gross national product. These projections require estimation of the types and volumes of goods and services the economy can produce or supply in both private and public sectors, and those that will be demanded by the public and private sectors. The third set of procedures translates overall economic projections into projections of industry activity, allocating estimated consumer spending among product groups and allocating products to producing industries. Estimated gross private domestic investment is in turn allocated between changes in business inventories and investments in construction (residential and nonresidential) and producer-durable goods (e.g., machinery and tools). The fourth set of procedures translates projections of industry output into projections of industry employment. This is done by a combination of procedures for estimating labor productivity (defined as output per unit of labor input) and weekly hours of work for each industry.

The final set of procedures yields projections of employment by occupation and by industry. It combines descriptions of staffing patterns obtained by periodic surveys with estimates of the

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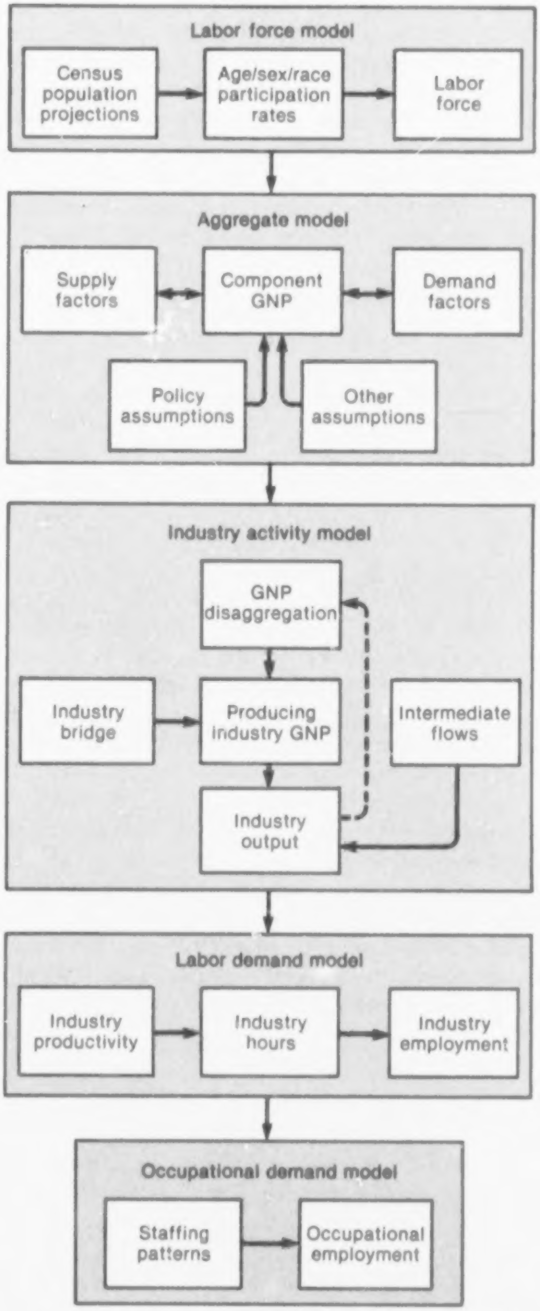
*Note that BLS has recently contracted with Chase Econometrics Associates, Inc., to use the Chase macroeconomic model to develop projections of aggregate economic activity, using assumptions and variables chosen by BLS. This arrangement will supplement in-house BLS modeling and analysis.

Figure 1.—Bureau of Labor Statistics Employment Projections System


Labor force model
Census population projections
Age/sex/race participation rates
Labor force
Aggregate model
Supply factors
Component GNP
Demand factors
Policy assumptions
Other assumptions
Industry activity model
GNP disaggregation
Industry bridge
Producing industry GNP
Intermediate flows
Industry output
Labor demand model
Industry productivity
Industry hours
Industry employment
Occupational demand model
Staffing patterns
Occupational employment

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, "BLS Economic Growth Model System Used for Projections to 1990."

number of jobs per industry. All of these procedures are described in detail in the BLS publication, *BLS Economic Growth Model System Used for Projections to 1990,* April 1982.

Shortcomings of Economic Estimates

As the description of the BLS procedures shows, large-scale economic models can take into account the growth and decline of different industries, the likelihood that individual industries adopting new technologies may maintain or increase output levels, and the responsiveness of industry employment levels to industry technology change. This framework prevents overattributing employment changes to single influences such as technology change, as it shows the consequences of combinations of influences. In their detail, however, the validity of the projections generated depends on the assumptions that underlie the formulation and operation of each aspect of the model and the integration of the different aspects. Moreover, the use of large-scale economic models carries the risk of oversimplifying complex processes and conveying an impression of greater analytical thoroughness than may actually exist.

Several questions have been raised about the assumptions used in large-scale economic forecasting models. The following list of some of the shortcomings of economic estimates reflects concerns raised by participants at the OTA Labor Markets and Industrial Relations Workshop, who debated whether economic models could adequately evaluate the impacts of programmable automation on employment. It also reflects concerns raised by others regarding economic modeling in general and modeling of technological change impacts in particular.

- *Labor Supply.* The growth of the labor force and change in labor force participation rates of specific groups depend in complex ways on demographic and economic factors. These relationships may not be captured in economic models which project labor supply and industrial output profiles separately.[*] Also, variations in the quality, rather than the quantity, of available labor may be beyond

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[*] BLS is currently working to improve its treatment of demographic and economic influences on the labor force.

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the scope of contemporary large-scale economic models. Consequently, the output of large-scale economic models may best be viewed as projected demands rather than employment levels, per se.

- *Technological Change.* It is unclear how well large-scale models account for changes in equipment technologies. Although the common practice of projecting future capital stock by extrapolating from past use of plant and equipment and past descriptions of industries and products suggests that economic models may be unable to capture the impacts of nontraditional equipment, experts disagree as to whether measures of specific new technology attributes are necessary for deriving economic estimates of employment change. See papers by L. Jacobson/R. Levy and F. Duchin, appendix C. In addition, economic models typically are constructed using the assumption that technological change is adopted to reduce unit costs, although it may also be adopted for other reasons (e.g., to meet health or pollution standards) leading to cost increases.
- *Staffing Patterns.* Employment change due to reorganization of production associated with programmable automation may not be captured where occupational employment is projected using staffing patterns derived from prior practices. Similarly, changes in occupational content may not be accounted for. BLS, for example, has found that many of the largest errors in its past estimates of occupational employment "resulted primarily from misestimates of industry-occupational staffing patterns."[7] The development of adequate staffing patterns would appear to require engineering analyses that take into account possible variations in the implementation of programmable automation, alternative levels of integration of manufacturing activities, and alternative approaches to accommodating existing company work forces.

Like engineering estimates, economic estimates have several shortcomings. However, while engineering estimates tend to highlight job displacement impacts of new technology, economic estimates are better suited for evaluating whether persons displaced from particular industries may find job opportunities in other industries requiring their skills, and therefore whether job displacement is likely to be associated with unemployment. How well they do this depends on how well they capture the different components of the economy and their interactions. Similarly, while engineering estimates may establish new needs for individuals with certain skills, economic estimates may more readily provide perspective on economywide demand for such individuals and therefore whether demand for certain skills or occupations is likely to exceed or fall short of supply. These differences arise because economic analyses as a rule model the interactions among segments of the economy, while engineering analyses do not, even though they may apply to the nationwide use of a technology. However, valid inferences regarding future unemployment and labor shortages require that engineering analysis, economic and industry analysis, and labor supply analysis be considered together.

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[7] Carey and Kasunic, op. cit.

BEYOND HARDWARE AND SOFTWARE: OTHER FACTORS TO BE CONSIDERED

In general, satisfactory projections of the magnitude and distribution of employment shifts associated with programmable automation should take into account a variety of factors that contribute to the direct and indirect effects of the new technology. Among these are changes in the organization of production, in the level of output among industries, and in the overall mix of employment opportunities in the economy. These changes will reflect the basic parameters described in the introduction (rate, nature, and diffusion pattern of technological change) and also the influence of institutional factors such as labor-management agreements and norms, which affect the rate and manner of application of new technologies. Labor-management relations are examined in appendix B.

Organization of Production

Change in the mix and volume of activities among users of programmable automation will depend on alteration of the organization of production (and concomitant changes in product lines) that may occur as a result of its use. As discussed in chapter 1, it is anticipated that the spread of programmable automation will involve both technologies embodied in automated equipment and systems and disembodied technologies in the form of organization and management changes. These changes may be most pronounced in small-volume or batch production settings:

> For a long time *the functional layout* in batch production, that is, all machines of the same kind are gathered in groups, has been as natural as the transfer line in mass production. Through the functional layout, machine utilization can be kept high, but at the expense of complex routing of parts through the shop and large buffers and inventories. . . . In the new manufacturing methods the main principle is to organize the factory according to *product-oriented layouts.* All machines needed to produce one product or one set of products are grouped together in a "subfactory," sometimes with its own administration. Each worker in product-oriented layouts attends several machines. In the functional layout we can with some simplification say that the materials wait for the machines while the machines in the product-oriented layout wait for the materials. The lead time (defined as the total time needed for material to be processed into a finished product) can thereby be reduced dramatically.[8]

Production may also be reorganized between facilities, as programmable automation facilitates regional and even international reorganization of production activities. For example, Ford Motor Co.'s Erika project (which resulted in the Escort and Lynx cars in the United States and similar cars in other markets) used "the largest collection of computer design hardware under one roof" to pool U.S. and European product design and analysis efforts, eliminating separate parallel efforts on different continents.[9] Although there has been much speculation among technology and industry analysts about potential employment effects of production reorganization, little reorganization appears to have taken place, in part because business management has either failed to understand or resisted such change, and in part because the integration aspects of programmable automation appear insufficiently developed.[10]

Output Level

The employment consequences of programmable automation production and use depend not only on the mix of manufacturing activities, but also on production volume for both automation and end products made with it. Since programmable automation will be sought by both new users and customers previously using other types of equipment, production volume should be evaluated by taking into account possible reductions in volume of other, older technology equipment and systems. This offset problem is generally recognized in evaluating the impacts of microelectronics-based (and other) technologies found in both new products and new production processes.

> (I)t is clear that microelectronic technologies will create jobs in those industries manufacturing novel electronic products. The $4 billion now being lavished on electronic watches, calculators, games, and other microelectronic products has spawned a whole industry that did not even exist a decade ago. According to a projection by . . . Arthur D. Little, the manufacture of these items, together with computers and other electronic equipment, could create about 1 million new jobs between 1977 and 1987 in the United States and Western Europe combined. About 1.5 million people are now employed in the electronics industry in the United States. But these jobs will not represent net additions to the work force, for they will be offset to some extent by job losses in the manufacture of goods with which the new microelectronics-based products are competing.[11]

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[8] "The Promotion of Robotics and CAD/CAM in Sweden," report from the Computers and Electronics Commission, Ministry of Industry (Sweden), 1981.

[9] *Automotive News,* Feb. 15, 1980.

[10] See for example: Bela Gold, "CAM Sets New Rules for Production," *Harvard Business Review,* November-December 1982.

[11] Colin Norman, "Microelectronics at Work: Productivity and Jobs in the World Economy," Worldwatch Paper 39, October 1980.

The net effects of programmable automation on user employment will depend on the effect it has on end-product prices and on foreign trade, product specialization, and other conditions in user markets in the United States and abroad. These factors, together with technology and general economic conditions, determine growth in domestic company sales volume.

Employment Opportunity Mix

Overall, employment effects of programmable automation will also depend on changes in employment opportunities throughout the economy. Economywide changes in employment activities depend in part on the pattern of diffusion of programmable automation and in part on the pattern of change in the mix of products available. Thus, although the apparent long-term decline in the manufacturing share of total U.S. employment (which began prior to widespread use of programmable automation) reflects the adoption of labor-saving technologies, the slow long-term growth in the absolute level of U.S. manufacturing employment illustrates the importance of sales volume and market growth (including the introduction of new products). It can be misleading to evaluate the employment impacts of new processes from the perspective of a constant mix of finished products because the number as well as the mix of goods and services provided to both producers and consumers is dynamic. Such evaluations are common, however, because the existing mix of products is known, while future product arrays are not.

LABOR SUPPLY

While employment demands may change because of the characteristics of programmable automation technologies and of industries producing and using them, change in employment (and unemployment) patterns also depends on the characteristics of the supply of labor: who is available to do the work offered by employers, how able people are to do different types of work, and whether there are too many or too few people with different abilities to do the work offered. The following is a brief overview of labor supply attributes and concerns.

Demography

The number of people willing and able to work, usually counted between the ages of 16 and 65, depends on several factors, including natural population growth,* immigration and emigration patterns, public health conditions, the age structure of the population (the proportions by age), and the willingness of people to work, given the levels of available wages and salaries and alternative sources of income. The overall size, growth rate, and age structure of the population are important measures of the availability of people in gross numbers to do work using particular technologies to support a given level of economic activity. Attitudes toward work and other social factors, which vary among geographic areas and ethnic groups, contribute to the actual numbers and types of people participating in the labor force.

Age structure and fertility patterns are particularly important influences on the makeup of the labor force. Fertility patterns, in combination with economic conditions and social norms, influence the labor force participation of women as well as the age structure of the population. The earlier and more frequently women give birth, for example, the younger the population is likely to be and the greater the (eventual) influx of new entrants to the labor force. Delays in and decreases in the incidence of marriage and childbearing over the past two decades have been causing the U.S. population to age by reducing the proportion of children. The age structure, in turn, influences: 1) the proportion of the population which is too young and/or too old to work and therefore dependent on the economic activity of the working-age population, 2) the overall rate of population growth, and 3) the numbers of new entrants to the labor force. Consequently, differences in age structure among countries influence national differences in employment patterns, preferences, and policies. The Japanese, for example, are reported to have shown early interest in programmable automation in part because "aging" of their population limited the supply of young workers.[12]

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*Natural population growth reflects mortality and in particular fertility (childbearing) rates, both of which may vary geographically, and among subgroups.

The composition of the American population has shifted toward older age groups more slowly than that of the Japanese population, but the supply of new entrants to the labor force is expected to begin a long-term decline in the 1980's. Federal projections of the U.S. population through the year 2050 show the number of teenagers to peak in 1980. The U.S. elderly population is expected to grow from the 1980 level of 25.7 million to 67.1 million by 2050, increasing from 11 to 21.7 percent of the population.[13] Unless the propensity of the elderly to work increases dramatically, this population shift will reduce the overall exposure of the U.S. labor force to job displacement, and it may eventually increase demand for labor-saving technologies.

Qualitative Attributes

Other characteristics of the labor force important to understanding employment trends are qualitative. They include level, type, and quality of education or training; skills; and preferences regarding different types of work. Education and training are important determinants of skills and therefore of the types of work individuals can do. However, educational attainment is an imprecise measure of the qualities of workers, since skills can be obtained through means other than formal instruction. A discussion of education, training, and retraining can be found in chapter 3.

Occupational Structure

The characteristics of the labor force, together with the array of jobs available, contribute to the occupational structure of an economy—the distribution of workers among occupations. Labor force attributes, and occupational structure in particular, change over time with changes in demography and with changes in social norms, both of which reflect economic conditions. For example, the absolute and relative growth in service sector employment has been associated with the growth in female labor force participation.

Key attributes of the 1980's labor force in the United States include growing proportions of older workers, relatively large proportions of women and minorities, relatively large proportions of college-educated workers, and declining numbers of people willing to work in low-level occupations.[14] Tables 3 and 4 display basic characteristics of the U.S. labor force.

It is important to note that, as long as different groups don't radically change their propensities to seek employment, it is relatively easy to describe the physical characteristics of the labor force 10 to 15 years into the future since these people have already been born. However, describing future occupational preferences and distribution is less straightforward, since there are many paths—not all measurable—for moving into different jobs and occupations and many alternative paths into, out of, and through the labor force.

Adaptability of Labor

A key issue in evaluating the adaptability of the labor force to changing labor demands—and therefore the likelihood of unemployment as a consequence of technology change—is the willingness and ability of people to perform different types of jobs if the jobs they have held, or would prefer to hold, become unavailable. Because this flexibility depends in part on "objective" worker traits such as specialized skills, and in part on "subjective" traits, such as personal preferences for certain kinds of jobs, it is difficult to evaluate the true fit between labor supply and labor demand in the wake of circumstances such as technology change that alter employment requirements. A poor fit may be revealed in under-

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[12] G. K. Hutchinson, "Flexible Manufacturing Systems in Japan" (Milwaukee, Wis.: University of Wisconsin Management Research Center, November 1977).

[13] Robert Pear, "Population Drop Predicted in U.S.," *New York Times*, Nov. 9, 1982.

[14] See, for example, Howard N. Fullerton, "How Accurate Were Projections of the 1980 Labor Force?" *Monthly Labor Review*, July 1982.

Table 3.—Noninstitutional Population and the Labor Force, 1929-82

(monthly data seasonally adjusted, except as noted)

Year or month	Noninstitutional population [1]	Armed Forces [1]	Civilian labor force					Unemployment rate (percent of civilian labor force)	Civilian labor force participation rate [2]		
			Total	Employment			Unemployment		Total	Males	Females
				Total	Agricultural	Nonagricultural					
	Thousands of persons 14 years of age and over							Percent			
1929		260	49,180	47,630	10,450	37,180	1,550	3.2			
1933		250	51,590	38,760	10,090	28,670	12,830	24.9			
1939		370	55,230	45,750	9,610	36,140	9,480	17.2			
1940	100,380	540	55,640	47,520	9,540	37,980	8,120	14.6	55.7	83.7	28.2
1941	101,520	1,620	55,910	50,350	9,100	41,250	5,560	9.9	56.0	84.3	28.7
1942	102,610	3,970	56,410	53,750	9,250	44,500	2,660	4.7	57.2	85.6	31.3
1943	103,660	9,020	55,540	54,470	9,080	45,390	1,070	1.9	58.7	86.4	36.0
1944	104,630	11,410	54,630	53,960	8,950	45,010	670	1.2	58.6	87.0	36.5
1945	105,530	11,440	53,860	52,820	8,580	44,240	1,040	1.9	57.2	84.8	35.9
1946	106,520	3,450	57,520	55,250	8,320	46,930	2,270	3.9	55.8	82.6	31.2
1947	107,608	1,590	60,168	57,812	8,256	49,557	2,356	3.9	56.8	84.0	31.0
	Thousands of persons 16 years of age and over										
1947	103,418	1,591	59,350	57,038	7,890	49,148	2,311	3.9	58.3	86.4	31.8
1948	104,527	1,456	60,621	58,343	7,629	50,714	2,276	3.8	58.8	86.6	32.7
1949	105,611	1,616	61,286	57,651	7,658	49,993	3,637	5.9	58.9	86.4	33.1
1950	106,645	1,649	62,208	58,918	7,160	51,758	3,288	5.3	59.2	86.4	33.9
1951	107,721	3,098	62,017	59,961	6,726	53,235	2,055	3.3	59.3	86.5	34.6
1952	108,823	3,593	62,138	60,250	6,500	53,749	1,883	3.0	59.0	86.3	34.7
1953 [3]	110,601	3,547	63,015	61,179	6,260	54,919	1,834	2.9	58.9	86.0	34.4
1954	111,671	3,350	63,643	60,109	6,205	53,904	3,532	5.5	58.8	85.5	34.6
1955	112,732	3,048	65,023	62,170	6,450	55,722	2,852	4.4	59.3	85.3	35.7
1956	113,811	2,856	66,552	63,799	6,283	57,514	2,750	4.1	60.0	85.5	36.9
1957	115,065	2,799	66,929	64,071	5,947	58,123	2,859	4.3	59.6	84.8	36.9
1958	116,363	2,636	67,639	63,036	5,586	57,450	4,602	6.8	59.5	84.2	37.1
1959	117,881	2,551	68,369	64,630	5,565	59,065	3,740	5.5	59.3	83.7	37.1
1960 [3]	119,759	2,514	69,628	65,778	5,458	60,318	3,852	5.5	59.4	83.3	37.7
1961	121,343	2,572	70,459	65,746	5,200	60,546	4,714	6.7	59.3	82.9	38.1
1962 [3]	122,981	2,827	70,614	66,702	4,944	61,759	3,911	5.5	58.8	82.0	37.9
1963	125,154	2,737	71,833	67,762	4,687	63,076	4,070	5.7	58.7	81.4	38.3
1964	127,224	2,738	73,091	69,305	4,523	64,782	3,786	5.2	58.7	81.0	38.7
1965	129,236	2,722	74,455	71,088	4,361	66,726	3,366	4.5	58.9	80.7	39.3
1966	131,180	3,122	75,770	72,895	3,979	68,915	2,875	3.8	59.2	80.4	40.3
1967	133,319	3,446	77,347	74,372	3,844	70,527	2,975	3.8	59.6	80.4	41.1
1968	135,562	3,534	78,737	75,920	3,817	72,103	2,817	3.6	59.6	80.1	41.6
1969	137,841	3,506	80,734	77,902	3,606	74,296	2,832	3.5	60.1	79.8	42.7
1970	140,272	3,188	82,771	78,678	3,463	75,215	4,093	4.9	60.4	79.7	43.3
1971	143,033	2,816	84,382	79,367	3,394	75,972	5,016	5.9	60.2	79.1	43.4
1972 [3]	146,574	2,449	87,034	82,153	3,484	78,669	4,882	5.6	60.4	78.9	43.9
1973 [3]	149,423	2,326	89,429	85,064	3,470	81,594	4,365	4.9	60.8	78.8	44.7
1974	152,349	2,229	91,949	86,794	3,515	83,279	5,156	5.6	61.3	78.7	45.7
1975	153,333	2,180	93,775	85,846	3,408	82,438	7,929	8.5	61.2	77.9	46.3
1976	158,294	2,144	96,158	88,752	3,331	85,421	7,406	7.7	61.6	77.5	47.3
1977	161,166	2,133	99,009	92,017	3,283	88,734	6,991	7.1	62.3	77.7	48.4
1978 [3]	164,027	2,117	102,251	96,048	3,387	92,661	6,202	6.1	63.2	77.9	50.0
1979	166,951	2,088	104,962	98,824	3,347	95,477	6,137	5.8	63.7	77.8	50.9
1980	169,848	2,102	106,940	99,303	3,364	95,938	7,637	7.1	63.8	77.4	51.5
1981	172,272	2,142	108,670	100,397	3,368	97,030	8,273	7.6	63.9	77.0	52.1
1982	174,450	2,179	110,204	99,526	3,401	96,125	10,678	9.7	64.0	76.6	52.6
1980											
Jan	168,625	2,081	106,546	99,872	3,313	96,559	6,674	6.3	64.0	77.7	51.6
Feb	168,846	2,086	106,637	99,963	3,387	96,576	6,674	6.3	63.9	77.6	51.5
Mar	169,073	2,090	106,394	99,677	3,412	96,265	6,717	6.3	63.7	77.5	51.3
Apr	169,289	2,092	106,552	99,204	3,318	95,886	7,348	6.9	63.7	77.4	51.4
May	169,494	2,088	106,892	98,922	3,385	95,537	7,970	7.5	63.9	77.6	51.5
June	169,735	2,092	106,832	98,769	3,309	95,460	8,063	7.5	63.7	77.5	51.4
July	170,030	2,099	107,169	98,816	3,331	95,485	8,353	7.8	63.8	77.5	51.5
Aug	170,217	2,114	107,116	98,829	3,247	95,582	8,287	7.7	63.7	77.3	51.5
Sept	170,419	2,121	107,148	99,104	3,448	95,656	8,044	7.5	63.7	77.3	51.4
Oct	170,624	2,121	107,438	99,327	3,362	95,965	8,111	7.5	63.8	77.3	51.6
Nov	170,814	2,119	107,596	99,567	3,387	96,180	8,029	7.5	63.8	77.3	51.6
Dec	171,007	2,124	107,446	99,650	3,486	96,164	7,796	7.3	63.6	77.0	51.6
1981											
Jan	171,229	2,125	108,012	99,964	3,420	96,544	8,048	7.5	63.9	77.3	51.8
Feb	171,406	2,121	108,175	100,143	3,340	96,803	8,032	7.4	63.9	77.2	52.0
Mar	171,581	2,128	108,471	100,504	3,356	97,148	7,967	7.3	64.0	77.3	52.1
Apr	171,770	2,129	108,866	101,006	3,519	97,487	7,860	7.2	64.1	77.4	52.3
May	171,956	2,127	109,101	100,968	3,371	97,597	8,133	7.5	64.2	77.4	52.4
June	172,172	2,131	108,440	100,393	3,360	97,033	8,047	7.4	63.8	76.7	52.1
July	172,385	2,139	108,602	100,748	3,320	97,428	7,854	7.2	63.8	76.8	52.1
Aug	172,559	2,160	108,762	100,709	3,396	97,313	8,053	7.4	63.8	76.9	52.1
Sept	172,758	2,165	108,375	100,104	3,358	96,746	8,271	7.6	63.5	76.7	51.7
Oct	172,966	2,158	109,028	100,355	3,374	96,981	8,673	8.0	63.8	76.7	52.2
Nov	173,155	2,158	109,254	100,229	3,389	96,840	9,025	8.3	63.9	76.8	52.3
Dec	173,330	2,164	109,066	99,677	3,219	96,458	9,389	8.6	63.7	76.7	52.0
1982											
Jan	173,495	2,159	109,034	99,688	3,379	96,309	9,346	8.6	63.6	76.5	52.1
Feb	173,657	2,168	109,364	99,695	3,367	96,328	9,669	8.8	63.8	76.6	52.3
Mar	173,843	2,175	109,478	99,597	3,367	96,230	9,881	9.0	63.8	76.5	52.3
Apr	174,020	2,176	109,740	99,484	3,356	96,128	10,256	9.3	63.9	76.6	52.4
May	174,201	2,175	110,378	99,994	3,446	96,548	10,384	9.4	64.2	77.0	52.7
June	174,364	2,173	110,147	99,681	3,371	96,310	10,466	9.5	64.0	76.5	52.7
July	174,544	2,180	110,416	99,588	3,445	96,143	10,828	9.8	64.1	76.5	52.9
Aug	174,707	2,196	110,614	99,683	3,429	96,254	10,931	9.9	64.1	76.6	52.9
Sept	174,889	2,198	110,858	99,543	3,363	96,180	11,315	10.2	64.2	76.8	52.8
Oct	175,069	2,188	110,752	99,176	3,413	95,763	11,576	10.5	64.1	76.7	52.7
Nov	175,238	2,180	111,042	99,136	3,466	95,670	11,906	10.7	64.2	76.8	52.8
Dec	175,380	2,182	111,129	99,093	3,411	95,682	12,036	10.8	64.2	76.6	53.0

[1] Not seasonally adjusted.

[2] Civilian labor force as percent of civilian noninstitutional population.

[3] Not strictly comparable with earlier data due to population adjustments as follows: Beginning 1953, introduction of 1950 census data added about 600,000 to population and about 350,000 to labor force, total employment, and agricultural employment. Beginning 1960, inclusion of Alaska and Hawaii added about 500,000 to population, about 300,000 to labor force, and about 240,000 to nonagricultural employment. Beginning 1962, introduction of 1960 census data reduced population by about 50,000 and labor force and employment by about 200,000. Beginning 1972, introduction of 1970 census data added about 800,000 to civilian noninstitutional population and about 333,000 to labor force and employment. A subsequent adjustment based on 1970 census in March 1973 added 60,000 to labor force and to employment. Beginning 1978, changes in sampling and estimation procedures introduced into the household survey added about 250,000 to labor force and to employment. Unemployment levels and rates were not significantly affected.

SOURCE: Department of Labor, Bureau of Labor Statistics.

Table 4.—Wage and Salary Workers in Nonagricultural Establishments, 1929-82
(thousands of persons; monthly data seasonally adjusted)

Year or month	Total wage and salary workers	Manufacturing			Mining	Construction	Transportation and public utilities	Wholesale and retail trade	Finance, insurance, and real estate	Services	Government	
		Total	Durable goods	Nondurable goods							Federal	State and local
1929	31,324	10,702			1,087	1,512	3,916	6,123	1,494	3,425	533	2,532
1933	23,699	7,397			744	824	2,672	4,755	1,280	2,861	565	2,601
1939	30,603	10,278	4,715	5,564	854	1,165	2,936	6,426	1,447	3,502	905	3,090
1940	32,361	10,985	5,363	5,622	925	1,311	3,038	6,750	1,485	3,665	996	3,206
1941	36,539	13,192	6,968	6,225	957	1,814	3,274	7,210	1,525	3,905	1,340	3,320
1942	40,106	15,280	8,823	6,458	992	2,198	3,460	7,118	1,509	4,066	2,213	3,270
1943	42,434	17,602	11,084	6,518	925	1,587	3,647	6,982	1,481	4,130	2,905	3,175
1944	41,864	17,328	10,856	6,472	892	1,108	3,829	7,058	1,461	4,145	2,928	3,116
1945	40,374	15,524	9,074	6,450	836	1,147	3,906	7,314	1,481	4,222	2,808	3,137
1946	41,652	14,703	7,742	6,962	862	1,683	4,061	8,376	1,675	4,697	2,254	3,341
1947	43,857	15,545	8,385	7,159	955	2,009	4,166	8,955	1,728	5,025	1,892	3,582
1948	44,866	15,582	8,326	7,256	994	2,198	4,189	9,272	1,800	5,181	1,863	3,787
1949	43,754	14,441	7,489	6,953	930	2,194	4,001	9,264	1,828	5,240	1,908	3,948
1950	45,197	15,241	8,094	7,147	901	2,364	4,034	9,386	1,888	5,357	1,928	4,098
1951	47,819	16,393	9,089	7,304	929	2,637	4,226	9,742	1,956	5,547	2,302	4,087
1952	48,793	16,632	9,349	7,284	898	2,668	4,248	10,004	2,035	5,699	2,420	4,188
1953	50,202	17,549	10,110	7,438	866	2,659	4,290	10,247	2,111	5,835	2,305	4,340
1954	48,990	16,314	9,129	7,185	791	2,646	4,084	10,235	2,200	5,969	2,188	4,563
1955	50,641	16,882	9,541	7,341	792	2,839	4,141	10,535	2,298	6,240	2,167	4,727
1956	52,369	17,243	9,833	7,411	822	3,039	4,244	10,858	2,389	6,497	2,209	5,069
1957	52,853	17,174	9,855	7,321	828	2,962	4,241	10,886	2,438	6,708	2,217	5,399
1958	51,324	15,945	8,829	7,116	751	2,817	3,976	10,750	2,481	6,765	2,191	5,648
1959	53,268	16,675	9,373	7,303	732	3,004	4,011	11,127	2,549	7,087	2,233	5,850
1960	54,189	16,796	9,459	7,337	712	2,926	4,004	11,391	2,629	7,378	2,270	6,083
1961	53,999	16,326	9,070	7,256	672	2,859	3,903	11,337	2,688	7,620	2,279	6,315
1962	55,549	16,853	9,480	7,373	650	2,948	3,906	11,566	2,754	7,982	2,340	6,550
1963	56,653	16,995	9,616	7,380	635	3,010	3,903	11,778	2,830	8,277	2,358	6,868
1964	58,283	17,274	9,816	7,458	634	3,097	3,951	12,160	2,911	8,660	2,348	7,248
1965	60,765	18,062	10,405	7,656	632	3,232	4,036	12,716	2,977	9,036	2,378	7,696
1966	63,901	19,214	11,282	7,930	627	3,317	4,158	13,245	3,058	9,498	2,564	8,220
1967	65,803	19,447	11,439	8,007	613	3,248	4,268	13,606	3,185	10,045	2,719	8,672
1968	67,897	19,781	11,626	8,155	606	3,350	4,318	14,099	3,337	10,567	2,737	9,102
1969	70,384	20,167	11,895	8,272	619	3,575	4,442	14,705	3,512	11,169	2,758	9,437
1970	70,880	19,367	11,208	8,158	623	3,588	4,515	15,040	3,645	11,548	2,731	9,823
1971	71,214	18,623	10,636	7,987	609	3,704	4,476	15,352	3,772	11,797	2,696	10,185
1972	73,675	19,151	11,049	8,102	628	3,889	4,541	15,949	3,908	12,276	2,684	10,649
1973	76,790	20,154	11,891	8,262	642	4,097	4,656	16,607	4,046	12,857	2,663	11,068
1974	78,265	20,077	11,925	8,152	697	4,020	4,725	16,987	4,148	13,441	2,724	11,446
1975	76,945	18,323	10,688	7,635	752	3,525	4,542	17,060	4,165	13,892	2,748	11,937
1976	79,382	18,997	11,077	7,920	779	3,576	4,582	17,755	4,271	14,551	2,733	12,138
1977	82,471	19,682	11,597	8,086	813	3,851	4,713	18,516	4,467	15,303	2,727	12,399
1978	86,697	20,505	12,274	8,231	851	4,229	4,923	19,542	4,724	16,252	2,753	12,919
1979	89,823	21,040	12,760	8,280	958	4,463	5,136	20,192	4,975	17,112	2,773	13,174
1980	90,406	20,285	12,187	8,098	1,027	4,346	5,146	20,310	5,160	17,890	2,866	13,375
1981	91,105	20,173	12,117	8,056	1,132	4,176	5,157	20,551	5,301	18,592	2,772	13,253
1982 p	89,619	18,849	11,114	7,735	1,122	3,912	5,057	20,547	5,350	19,000	2,733	13,051
1981:												
Jan	90,909	20,171	12,120	8,051	1,102	4,315	5,139	20,380	5,252	18,352	2,798	13,400
Feb	90,913	20,148	12,097	8,051	1,113	4,240	5,145	20,422	5,264	18,382	2,789	13,410
Mar	91,014	20,197	12,143	8,054	1,124	4,267	5,153	20,438	5,270	18,414	2,780	13,371
Apr	91,099	20,275	12,201	8,074	978	4,281	5,163	20,508	5,286	18,480	2,774	13,354
May	91,131	20,332	12,237	8,095	985	4,223	5,158	20,543	5,295	18,517	2,776	13,302
June	91,286	20,334	12,246	8,088	1,137	4,185	5,162	20,590	5,302	18,556	2,777	13,243
July	91,396	20,379	12,266	8,113	1,164	4,175	5,168	20,620	5,311	18,615	2,775	13,189
Aug	91,322	20,311	12,228	8,083	1,180	4,146	5,168	20,650	5,319	18,654	2,769	13,125
Sept	91,363	20,267	12,184	8,083	1,192	4,124	5,181	20,660	5,328	18,707	2,764	13,140
Oct	91,224	20,097	12,059	8,038	1,195	4,101	5,162	20,654	5,325	18,773	2,757	13,160
Nov	90,996	19,903	11,901	8,002	1,202	4,071	5,150	20,623	5,324	18,815	2,749	13,159
Dec	90,642	19,676	11,724	7,952	1,206	4,026	5,128	20,524	5,331	18,834	2,756	13,161
1982:												
Jan	90,460	19,517	11,622	7,895	1,201	3,966	5,125	20,630	5,326	18,831	2,741	13,123
Feb	90,459	19,454	11,575	7,879	1,203	3,974	5,115	20,670	5,326	18,867	2,737	13,113
Mar	90,304	19,319	11,490	7,829	1,197	3,934	5,100	20,655	5,336	18,904	2,736	13,123
Apr	90,083	19,169	11,375	7,794	1,182	3,938	5,094	20,584	5,335	18,929	2,730	13,122
May	90,166	19,115	11,332	7,783	1,152	3,988	5,101	20,652	5,342	18,963	2,728	13,125
June	89,839	18,930	11,203	7,727	1,124	3,940	5,078	20,595	5,352	18,988	2,739	13,093
July	89,535	18,813	11,133	7,680	1,100	3,927	5,044	20,615	5,359	19,042	2,737	12,898
Aug	89,312	18,672	10,993	7,679	1,086	3,899	5,025	20,550	5,360	19,048	2,739	12,933
Sept	89,267	18,572	10,900	7,672	1,075	3,883	5,031	20,492	5,367	19,084	2,734	13,029
Oct	88,860	18,325	10,666	7,659	1,058	3,856	5,007	20,441	5,357	19,074	2,723	13,019
Nov p	88,684	18,183	10,555	7,628	1,051	3,848	4,994	20,390	5,362	19,125	2,726	13,005
Dec p	88,518	18,134	10,533	7,601	1,036	3,818	4,979	20,297	5,376	19,143	2,728	13,007

Source: Department of Labor, Bureau of Labor Statistics.

employment* and unemployment, and in labor shortages.

Labor shortages exist where a sufficient number of particular types of people are unavailable for work at prevailing wages. Concern has been expressed by people in industry and in government about the economic effects of shortages in highly skilled craft and technical occupations, from machinists to certain types of engineers.** Alleged shortages have been cited as a motivation for investments in automation, and also in retraining. While retraining can ease shortages by increasing the supply of skilled workers, raising wages is another method of stimulating supply, although employers are often unwilling or unable to do this. Note that, for skills that take years to develop, instituting training programs (or raising wages) will not eliminate a shortage immediately.

A satisfactory analysis of labor supply issues associated with programmable automation should address such issues as contrasts in the composition of the U.S. labor force with that of other countries producing and using programmable automation, and the extent to which the production and use of programmable automation are influenced by labor shortages. Such issues are fundamental to the identification of components of the U.S. labor force that may be particularly helped or harmed by the spread of programmable automation, and the determination as to whether anticipated changes in the U.S. labor force are likely to cushion or exacerbate impacts that might arise from programmable automation.

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*For example, according to BLS many college graduates during the 1970's took jobs not requiring college degrees.

**The extent of current and possible future labor shortages that may affect the development or diffusion of programmable automation is unclear. Among the reasons that shortages are hard to measure are the following: 1) Federal programs do not collect occupational shortage statistics (due to cost and data reliability problems), 2) available data do not accurately capture employee mobility within and between occupations, 3) occupational classifications among firms and Federal statistical programs are inconsistent, and 4) employer and union surveys tend to be statistically unreliable. A recent analysis by BLS found after evaluating data from several sources that a machinist shortage could be neither established nor disproved.[15]

[15] Neal H. Rosenthal, "Shortages of Machinists: An Evaluation of the Information," *Monthly Labor Review*, July 1982.

WORKING ENVIRONMENT

Introduction

Programmable automation may change not only the numbers and types of people working in manufacturing, but also the circumstances of work—what may be called the working environment. The ways in which programmable automation is applied will determine how it affects the working environment. This discussion of the potential implications of programmable automation for the working environment will address some of the issues concerning worker safety and health, human factors, job content, and structure of work.

Expressions of concern about the effects of technology on the conditions of work have increased in the United States over the past two decades. For a long time it was assumed by management that the benefits of more efficient production achieved through the introduction of new technologies far outweighed any negative effects on the work force. In other words, the assumption was that people could always adapt in some way to the requirements imposed by the technology.[16]

As in other countries, concerns about workplace conditions contributed to the growth of the labor movement in the United States. Since the mid-1960's, changing social and economic environments, characterized by an emerging awareness of individual rights and well-being, increased worker dissatisfaction, and declining productivity, have increased the importance of the working environment to both management and government, as well as labor. Workplace issues in manufacturing are currently being addressed in a number of ways, such as: 1) emphasis on human factors in the design of manufacturing equipment; 2) innovations in the structure of work; 3) increased cooperation between management and labor in solving workplace problems; and 4) a variety of experiments in worker participation (such as quality control circles and quality of working life programs) intended to give workers greater input into decisions directly affecting their jobs. See table 5. These developments have met with varying degrees of success and commitment from management and labor. Nevertheless, they are part of the backdrop to the spread of programmable automa-

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[16] Joel A. Fadem, "Automation and Work Design in the United States," in *International Comparative Study on Automation and Work Design*, International Labour Office, Geneva, January 1982, p. 25.

Table 5.—Labor-Management Committees on Industrial Relations Issues, Safety, and Productivity by Industry (agreements covering 1,000 workers or more, Jan. 1, 1980)

			Labor-management committees on—					
	All agreements		Industrial relations issues[a]		Safety[b]		Productivity[c]	
Industry	Agreements	Workers	Agreements	Workers	Agreements	Workers	Agreements	Workers
All industries	***1,550***	***6,593,800***	***60***	***245,400***	***572***	***2,867,850***	***81***	***1,091,350***
Manufacturing	***750***	***3,025,150***	***39***	***148,150***	***413***	***1,835,550***	***58***	***845,300***
Food, kindred products	79	234,200	6	25,500	35	140,400	5	69,700
Tobacco manufacturing	8	21,800	—	—	—	—	—	—
Textile mill products	11	28,850	—	—	1	1,200	—	—
Apparel	31	207,900	—	—	1	1,000	—	—
Lumber, wood products	11	17,100	4	4,850	7	9,950	1	1,000
Furniture, fixtures	17	23,100	1	1,000	8	7,400	1	1,000
Paper, allied products	42	65,000	1	1,100	18	27,650	1	1,200
Printing and publishing	15	31,600	1	1,000	3	10,800	2	9,100
Chemicals	36	61,700	1	1,200	21	30,850	1	2,000
Petroleum refining	15	25,500	—	—	10	18,900	—	—
Rubber and plastics	14	68,850	4	29,250	14	68,850	2	16,450
Leather products	11	23,100	—	—	2	3,200	—	—
Stone, clay, and glass	35	93,600	1	1,000	26	66,550	—	—
Primary metals	88	460,600	7	40,150	76	429,700	33	316,850
Fabricated metals	41	97,000	2	3,200	25	66,150	3	5,050
Nonelectrical machinery	81	242,150	4	10,350	48	141,800	2	2,100
Electrical machinery	83	323,750	3	8,200	42	130,300	—	—
Transportation equipment	112	957,100	3	20,000	68	656,150	7	420,850
Instruments	11	27,650	1	1,350	4	16,700	—	—
Miscellaneous manufacturing	9	14,600	—	—	6	8,000	—	—
Nonmanufacturing	***800***	***3,568,650***	***21***	***97,250***	***159***	***1,032,300***	***23***	***246,050***
Mining, crude petroleum, and natural gas	16	169,050	2	6,000	13	161,200	3	10,100
Transportation[d]	62	469,550	1	9,000	22	289,400	12	208,350
Communications	80	620,000	4	45,000	37	316,050	1	1,550
Utilities, electric and gas	81	210,700	2	4,300	35	108,050	2	4,900
Wholesale trade	12	23,900	2	3,950	1	1,050	—	—
Retail trade	123	405,200	2	2,200	10	19,050	—	—
Hotels and restaurants	31	148,300	—	—	1	10,000	—	—
Services	66	323,450	5	22,100	6	8,800	2	3,650
Construction	327	1,195,000	3	4,700	34	118,700	3	17,500
Miscellaneous nonmanufacturing	2	3,500	—	—	—	—	—	—

[a] A labor-management committee on industrial relations issues is a joint committee which studies issues, for example, subcontracting, seniority, and wage incentives, away from the deadlines of bargaining and makes recommendations to the negotiators. It also may be referred to as a "prebargaining" or "continuous bargaining" committee. It should not be confused with labor-management committees which meet periodically to discuss and resolve grievances and in-plant problems.

[b] A labor-management safety committee is a joint committee which meets periodically to discuss safety problems, to work out solutions, and to implement safety programs in the plant.

[c] A labor-management committee on productivity is a joint committee which meets periodically to discuss in-plant production problems and to work out methods of improving the quantity and quality of production.

[d] Excludes railroads and airlines.

NOTE: Nonadditive.

SOURCE: U.S. Department of Labor, "Characteristics of Major Collective Bargaining Agreements, January 1, 1980."

tion, and will influence how these technologies are implemented and how they affect the overall conditions of work.

Occupational Safety and Health

Occupational safety and health issues may be clearer than others associated with programmable automation. For example, the application of robots to painting and welding tasks is widely acknowledged as a measure that reduces worker exposure to occupational hazards by removing workers from the hazards. However, the use of robots and other forms of programmable automation may give rise to workplace hazards that are new and perhaps unanticipated.

The hazards associated with programmable automation are likely to be similar to those associated with industrial machinery, video display terminals (VDTs), and other types of equipment. With the introduction of programmable automation, there may be a shift of occupational safety and health concerns in manufacturing away from those directly involving machinery toward VDT-related issues. VDTs will become more numerous in manufacturing, and one possible outcome of the spread of programmable automation is an increase in the percentage of manufacturing workers using VDTs and a decrease in the percentage operating machinery. The eyestrain, stress, and back, neck, and shoulder problems recently documented by the National Institute for Occupational Safety and Health among workers who use VDTs for extended periods of time may become a problem for those using computer-aided design and manufacturing (CAD/CAM) systems.[17]

Unlike many older manufacturing technologies, programmable automation technologies are being developed in an era of greater awareness of occupational safety and health issues. Part of that context includes a body of Occupational Safety and Health Administration (OSHA) standards as well as a sophisticated set of nongovernmental technical standards. The applicability of current OSHA standards to the use of programmable automation will depend on the type of industry or nature of the operation involved. It is unclear whether or not programmable automation may give rise to a need for further OSHA standards.

Human Factors

Programmable automation may change the way job performance is evaluated in manufacturing. The computer and communications capabilities of programmable automation permit the recording and monitoring in remote locations of many aspects of equipment and system utilization, such as the number of operations performed per minute or per hour. Such monitoring would provide management with more information than individual piece counts conducted at the end of a day or week and other traditional measures of performance. Although sophisticated monitoring functions are not a necessary feature of programmable automation products, their possible use may reduce worker discretion in performing tasks and raise levels of stress among workers. Such results have been observed where office automation has been implemented with sophisticated monitoring features, such as tabulation of keystroke-per-minute rates.[18] On the other hand, if programmable automation requires fewer workers per machine, it may reduce the amount of direct personal supervision required.

Many of the effects, both physical and psychological, of programmable automation on people in the workplace will depend on the care and thought that go into the basic design of automated equipment and systems, and on whether the designers are concerned about human factors issues. Consideration of human factors involves first analyzing the roles people will play in a working environment using programmable automation, and then "examining such human factors engineering issues as design, procedurization, and protection."[19] Design engineers who do not work on the shop floor or in other manufacturing settings may not be sufficiently sensitive to the physiological and psychological needs of the user. Whether or not the user is involved in the design process may determine to what extent the human needs of manufacturing personnel will be translated into equipment and systems designs.[20]

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[17] "Health Hazards for Office Workers: An Overview of Problems and Solutions in Occupational Health in the Office," *Working Women Educational Fund,* 1981, p. 22.

[18] Judith Gregory, Testimony for 9 to 5, National Association of Working Women, Hearings, House Subcommittee on Education and Labor of the Committee on Education and Labor, June 23, 1982, p. 10.

[19] H. McIlvaine Parsons and Greg P. Kearsley, "Human Factors and Robotics: Current Status and Future Prospects," Human Resources Research Organization, Alexandria, Va., prepared for U.S. Army Human Engineering Laboratory, October 1981, p. 13.

Although worker involvement in the design process would seem logical on the surface, it may also present a dilemma for manufacturing employees. While on the one hand their participation could improve the consideration of human factors, it could also facilitate the design of equipment that may eliminate jobs. This dilemma may inhibit the full participation of many workers in such activities as quality control circles and quality of working life programs.

Job Content

Programmable automation may affect job content in a number of ways and its impact on skill requirements is likely to be highly variable. By design, automated equipment and systems may alter the skills required for certain aspects of the production process, but the implications for specific jobs (e.g., in terms of the number and variety of tasks comprised) depend on how programmable automation is implemented. The impacts of programmable automation on skill levels are uncertain. While some jobs clearly will require a higher level of skill, others may require a lesser level, largely because much of the process-control decisionmaking may be incorporated into computer-controlled equipment and systems. It is unclear at this time whether the effects on skill levels are inherent in the programmable automation technology, or the extent to which innovative use provides a choice. Whether programmable automation will provide jobs that are more stimulating and satisfying overall than those in traditional manufacturing environments is uncertain. However, it is unlikely that all programmable automation jobs will provide more challenge, variety, and responsibility—nor does everyone require it.[21] There will probably always be monotonous jobs, and many workers accept this in return for such other benefits as fair wages and job security.[22]

Depending on how tasks are organized, programmable automation may allow an increase in the variety of tasks a worker performs.

> There is also a close relation between the manufacturing technology chosen and the organization of work. However, technology is not the single determinant, so there is no specific organization corresponding to the use of a CAD/CAM system. Organizational philosophy has a predominant role, for example if one believes in complementary specialization of skills or in overlapping skills. The CAD/CAM may be a loyal servant to any work organization, provided that those who design and adapt the system know what they want.[23]

A restructuring of work in which both technical and human considerations are given equal treatment could offset the negative effects of changing skill requirements that may arise where old patterns of work organization persist.

Programmable automation may lead to changing roles and responsibilities at all levels, affecting both the nature of jobs and the distribution of power. The difficulties of reorganizing companies are well recognized. For example, change in the hierarchical structure (and thus control) brought about by the introduction of new technology may meet with resistance from those who might lose some authority.[24] Consultants and trade and professional associations concerned with programmable automation have devoted much attention to the management challenges of successful use of programmable automation over the past few years. Clearly, management planning, practices, and policies will be key factors in how the introduction, implementation, and operation of programmable automation affects the overall working environment.

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[20] Fadem, op. cit., p. 51.

[21] Eric Trist, "The Evolution of Socio-Technical Systems: A Conceptual Framework and an Action Research Program," Occasional Paper No. 2, Ontario Quality of Working Life Center, June 1981, p. 32.

[22] Sar A. Levitan and Clifford M. Johnson, *Second Thoughts on Work* (Kalamazoo, Mich.: W. E. Upjohn Institute for Employment Research, 1982), p. 212.

[23] "The Promotion of Robotics and CAD/CAM in Sweden," report from the Computers and Electronics Commission, Ministry of Industry (Sweden), 1981.

[24] Robert Schrank, *Ten Thousand Working Days* (Cambridge, Mass.: The MIT Press, 1978), p. 221.

Chapter 3

Education, Training, and Retraining

Chapter 3

Education, Training, and Retraining

INTRODUCTION

At various stages in U.S. history, changes in workplace operations and procedures in all sectors of the economy have resulted in changes in education, training, and retraining requirements for those employed or preparing for employment. Changes in instructional requirements for manufacturing-related work have been particularly dramatic. In some instances, they have been so extensive and widespread that they have triggered changes in the structures of institutions and organizations engaged in the delivery of education, training, and retraining services or the emergence of new instructional providers. For example, new production techniques introduced during the Industrial Revolution had much to do with the creation of a system of free public education, since large-scale production and continued industrial expansion required a literate work force capable of functioning on production lines, supervising manufacturing operations, keeping administrative records, and performing other functions. During this period, both industry and the labor movement became involved in the design and implementation of instructional programs to address short-term and special needs they felt could not be met either within a system of general instruction or through the public and private vocational programs that were emerging.[1]

Another era of substantial industrial change occurred in the 1960's, when the aerospace/defense industry underwent tremendous expansion and mechanization as a result of a concern over national defense and a national commitment to manned space exploration. Under provisions of the National Defense Education Act,[2] an example of legislation that led to the establishment of national policy for certain forms of occupational instruction, U.S. educational institutions were charged with coordinating efforts to prepare thousands of individuals for careers in science, engineering, and related fields. Training in these fields was considered necessary in order to develop the expertise and the technological base essential to creating a strong system of national defense and to meeting the challenges of space. Rapid technological change in aerospace/defense and other industries affected by these nationwide efforts required the continued involvement of business and labor in specialized instruction, to ensure that skill levels advanced at the same rate as applications of new machinery. However, when national priorities changed, this cross-sector commitment to linking advances in technology with the upgrading of skills within aerospace/defense and related industries disappeared. Since that time, the development of the human resource for these industries has been approached in more parochial ways by business, labor, educators, and government.

In these and other instances of changing education and training requirements, three factors have impeded the development of a coordinated, flexible system for occupational instruction in the United States. First, the absence of long-range, public and private projections of skill requirements, particularly those that highlight changes in skill levels and in core skill requirements within occupations, has hindered the development and delivery of instructional programs before industrial demand reaches critical proportions.* For example, the Electronic Industries Association reports that within the software technology field, certain highly specialized skills possessed by electrical engineers and computer scientists are interchangeable. Although not captured in more formal projections, this interchangeability will affect recruitment strategies and, in turn, supply within both occupational groups. The net result may be that current and projected shortages of computer science graduates may also be seen in electrical engineering and yet may not be reflected in formal occupational projections.* Second, a history of responding to changing industrial skills requirements as crises arise has perpetuated a fragmented approach to education and training. Little or no planning or coordination of efforts takes place among traditional educators, business, labor, government, and others. Third, rapid technological change has placed great strain on educators as they attempt to adapt instruction to the requirements of new technology, while at the same time they address other changes in instructional needs.

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[1] For additional information on the history of education and training in the United States, see *Informational Technology and Its Impact on American Education* (Washington, D.C.: U.S. Congress, Office of Technology Assessment, November 1982), OTA-CIT-187.

[2] National Defense Education Act of 1958 (Public Law 85-864, Sept. 2, 1958); National Defense Education Act Amendments, 1964 (Public Law 88-665).

*There are those who would argue that establishment of a coordinated, flexible system for occupational instruction in which projections of national as well as regional demand are taken into account is not the best approach and that actual rather than projected demand within local labor markets should determine public and private sector human resource development activities.

The application of programmable automation in manufacturing operations has the potential to trigger widespread changes in education and training requirements. Robots and other forms of programmable equipment and systems may change the organization of the manufacturing process, the character of the production line, the occupational mix, and the human-machine relationship. The utilization of programmable automation, depending on its impact on employment levels within specific occupations, may also necessitate the retraining of individuals for occupations in other sectors.

This section of the technical memorandum examines the changing role of education, training, and retraining in the United States; describes how industry and labor engage in instructional services delivery; presents some current views held by representatives of industry, labor, and the educational community concerning changes in instructional requirements and providers; and outlines selected critical issues for those engaged in instructional design and delivery, in light of possible widespread use of programmable automation. This picture of education, training, and retraining, when viewed in light of present and future trends in the labor market, should facilitate the identification of new opportunities, problems, and issues in education and training policy.**

Changing Role of Education, Training, and Retraining

Formal instruction has always been viewed as an important part of the human development process in the United States. Since the colonial period, a variety of institutions and organizations have been established to deliver education and/or training services to the general public or to special segments of the population. Some of these institutions and organizations consider the provision of instructional services their primary mission; others, such as corporations and labor unions, view education and/or training as one of a number of activities in which they are engaged. The recent OTA study, *Informational Technology and Its Impact on American Education,* found that today, instructional services are available from an even wider variety of sources, including electronic-based services delivered directly to the home.[3]

As U.S. economic and social conditions have changed over the years, the role of education and training in the lives of all citizens has changed as well. Formal instruction was once viewed as a luxury that was unavailable to a large percentage of the population. Then, after a system for public education was established, the role of instruction became the initial preparation of young people to assume responsibilities as productive numbers of society. In the 1980's, instruction has come to be seen as a lifelong process that enables individuals of all ages to cope with economic and social change.

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*Alternatively, it could be argued that electrical engineers, given an adequate supply, could be recruited to fill computer science jobs and eliminate projected shortages for that occupational group, but not in ways that could be foreseen by current methods of formal projection. In addition, recruitment for computer science jobs from the ranks of individuals with liberal arts training such as music and foreign languages, a practice that has proven quite successful, is not captured in formal projections of demand for those disciplines.

**A number of investigations are now underway in the private sector that could considerably improve the understanding of changing education, training, and retraining requirements *in general* and requirements related to the utilization of programmable automation in manufacturing *in particular.* One such effort is a survey of education and training representatives in 1,000 corporations, conducted by *Training Magazine,* designed to identify current instructional needs and in-house program content. A second survey, initiated by the Society of Manufacturing Engineers (SME), has been designed to elicit from a sample of the SME membership, as well as from selected educators, views on instructional requirements that may stem from the application of computer-aided design (CAD) and computer-aided manufacturing (CAM). Knowledge derived from these investigations and others in progress will be incorporated into the final report.

[3] *Informational Technology and Its Impact on American Education,* op. cit.

Questions concerning who receives instruction, who determines the content, who provides the instruction, what modes of delivery are utilized, how much instruction costs, and who pays for it have received considerable discussion throughout modern U.S. history and have served to shape national education and training policy. Education and training for work and who should provide them have been controversial subjects since the Industrial Revolution.

Participation in Instructional Programs

Due to a variety of forces, including the accelerating rate of technological change and growth in foreign trade, some workers, especially those in manufacturing environments, are finding that their skills are not adequate either to continue to perform their current jobs or, if they are displaced, to secure new jobs. Others may find that they are overskilled for their positions, due to the introduction of computer-based equipment and systems as well as other workplace changes. Changes in skill requirements and skill levels are affecting all manufacturing occupations, from the production line worker to the professional engineer. In response, many individuals are seeking additional training in order to keep pace with technological and economic change, although it is unclear from available data which occupational groups they may represent and whether they are predominantly white- or blue-collar. The relative quality of the instruction, and therefore its usefulness, is also difficult to determine from the available data. The Current Population Survey's Special Survey of Participation in Adult Education revealed that over 21 million persons 17 years old and over, or some 13 percent of the adult U.S. population, participated in adult education programs in 1981. An analysis of enrollments in 37,381 courses revealed that approximately 60 percent had participated for job-related reasons. In 9,260 cases, courses were provided by employers; in another 12,287 cases, employers paid enrollment fees for courses delivered outside the company. Professional and technical workers comprised the largest percentage of those enrolled—some 30 percent (there is no distinction made in the survey as to whether respondents are salaried or hourly employees). About 54 percent of the participants were under 35 years of age; 12 percent were over 55.[4]

Industry and Labor as Instructional Providers

Since the mid-19th century, both business and the labor movement have contributed to or participated in the design and delivery of instructional programs. Formal, in-house instruction is more common in larger business and labor organizations. At present business and labor both sponsor a variety of employee education and training activities, such as secondary-level remedial courses, traditional apprenticeships, and postsecondary degree and nondegree programs.

The American Society for Training and Development estimates that U.S. industry now spends approximately $40 billion annually on education and training programs for employees. The estimate excludes instructor fees or other administrative costs, such as equipment and enrollee travel expenses. Although rather dated, the results of a study of corporate-based training and education conducted by the Conference Board in 1974-75 indicated that in 1973-74, 75 percent of the 610 firms responding provided some in-house courses, 89 percent had tuition aid or refund programs, and 74 percent sponsored the enrollment of selected employees, usually managers and professionals, in courses offered outside the company during working hours.* The Conference Board estimated that in firms with 500 or more employees, with a combined employee base of 32 million, about 3.7 million, or 11 percent, were enrolled in in-house courses during working hours and another 2 percent (or 700,000) were enrolled during nonworking hours. Participation was more common for salaried than for hourly employees. The survey also showed that firms with less than 1,000 employees relied more on hiring trained individuals and on informal, on-the-job training.[5]

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[4] "Participation in Adult Education, May 1981," *National Center for Education Statistics Early Release*, June 1982.

*Roughly 1.3 million employees in responding companies were taking advantage of tuition assistance programs.

[5] Seymour Lusterman, *Education in Industry* (New York: The Conference Board, Inc., 1977), pp. 11-12.

This finding is consistent with other evidence that firms with up to 500 employees depend on informal, on-the-job training for all types of staff, since formal instruction programs are often too expensive for businesses of this size.[6]

Labor unions and labor organizations are also active sponsors and providers of employee education and training. Historically, unions have promoted liberal arts education in addition to more narrowly focused occupational education. Labor unions and labor organizations have been a strong force in shaping the popular view of education as the key to social and economic advancement.[7] Like some companies, unions sponsor 2- and 4-year degree programs at community colleges, colleges and universities, as well as single courses in labor studies. Unions also cosponsor apprenticeship programs with industry, providing specialized training in a skilled trade, craft or occupation at the worksite, and on-the-job instruction.

According to Bureau of Labor Statistics (BLS) figures, at the close of 1979 there were 323,866 persons enrolled in apprenticeship programs. Unpublished BLS estimates of apprenticeship enrollments are 320,000 persons in 1980, 316,000 in 1981, and 287,000 in 1982. While the drop in enrollment reflects reduced public and private funding levels, unions report there is no evidence to suggest that interest in apprenticeship has declined. Reductions in U.S. Employment and Training Administration apprenticeship and preapprenticeship grants to individual labor unions, labor organizations such as the AFL-CIO's Human Resources Development Institute, and community-based organizations such as the National Urban League, have diminished recruitment for and enrollment in apprenticeships. Deteriorating economic conditions within industries providing apprenticeship opportunities may be another factor in declining enrollments.

Manufacturing-Related Instruction

Management and labor have been the major providers of employee instruction beyond initial occupational preparation, since public sponsorship of training and retraining of noneconomically disadvantaged adults has been limited. The extent to which individuals working in manufacturing participate in education, training, and retraining programs offered by industry, labor unions, or other private or public providers is unknown. However, within corporate-based instruction as a whole, fewer courses are designed specifically for production line workers (excluding apprenticeship) than any other occupational group. Training industry representatives suggest that corporate instructional efforts have not previously concentrated on technical training other than in programs provided for engineering or data processing personnel.* This situation may change as U.S. manufacturing firms become familiar with new design and production technologies.

Another reason that technical and skills training do not receive more emphasis in corporate-based instructional programs may be their relative complexity, which requires demonstration of skill as well as knowledge transfer. This implies that technical courses and programs must emphasize hands-on practice and include a performance test to ensure mastery of skills.[8] Technical and skills training also require instructors with an understanding of current manufacturing processes as well as in-depth knowledge of the subject matter. These requirements result in high costs for establishing and maintaining an instructional program. In nonunion facilities, work-related instruction may depend on the advantages companies see in providing continuing education experiences in-house or through tuition reimbursement plans.

Different views exist as to how much emphasis unions place on instruction beyond apprenticeship. Some suggest that such instruction has heretofore not been a great concern of union members who therefore have addressed it in labor-management agreements in only a general way, through tuition reimbursement provisions. However, since the late 1960's, layoffs in auto, steel, and other industries have given rise to agreements *featuring* education and training benefits. One indicator of expanded worklife learning may be future emphasis on education and training benefits in labor-management agreements.[9]

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[6] Interview with Jerome Pelaquin, Chairman, Technical and Skills Training Special Interest Group, American Society for Training and Development, July 1982.

[7] Paul E. Barton, *Worklife Transitions: The Adult Learning Connection* (New York: McGraw-Hill, 1982), ch. 7.

*Technical training is the term commonly used to describe work-related instruction for individuals who perform technical procedures or who work in environments where technologies have been applied.

[8] Stanley J. Holden, "Business, Industry and Labor: Linkages Between Training and Employment," in *Job Training for Youth*, Robert E. Taylor, Howard Rosen, Frank C. Pratzner (eds.) (Columbus, Ohio: The National Center for Research in Vocational Education, The Ohio State University, 1982), p. 360.

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[9] Barton, op. cit., pp. 125-126.

TECHNOLOGY AND MANUFACTURING: CHANGES IN INSTRUCTIONAL REQUIREMENTS

Discussions of the impacts of automation on education and training for the American worker are hardly new. The National Commission on Technology, Automation, and Economic Progress (hereafter "Automation Commission"), in its 1966 report, noted shifts in skill requirements occurring during that decade.[10] The report cites rapidly increasing employment levels of the highly skilled, as manifested in a technical work force that had grown from 6.6 percent of the total in 1947 to 12.2 percent of the total in 1964, and significant shifts during the same period from manual to white-collar work. The Commission report notes the trend toward more formal schooling, particularly higher education, as well as the growing education gap between the skilled and the unskilled. The Commission observed:

> The encouragement of an adaptable labor force fostered through education and training is second in importance only to the provision of adequate employment opportunities in the facilitation of adjustment to technological and other change . . . We wish to emphasize at the onset that we regard the goals of education as far transcending economic objectives. These goals go beyond economic progress to the development of individuals as persons and as responsibile citizens. A clear division of education into its "economic" and "noneconomic" aspects is impossible . . . From the purely economic point of view, education has three principal effects: 1) it can increase the versatility and adaptability of people with respect to change; 2) it can open up increasing opportunity to persons who might otherwise have difficulty in finding and holding employment; and 3) it can increase the productivity of workers at any level of skill or ability. Though education is much more than a means of economic progress, it is a decisive factor in the economic advancement of any country.[11]

Commission members acknowledged growth in corporate-based employee instructional programs, and they considered widespread basic skills deficiencies an impediment to future economic growth. Among their recommendations were:

- provision of quality compensatory education to all who need it;
- improvement of "quality and quantity" of primary and secondary education, especially in economically depressed areas, in order to achieve equity of access and equity of opportunity;
- universal high school graduation;
- deferral of vocational training until after high school, to ensure that individuals receive a general education to prepare them for subsequent occupational education and to instill an appreciation for education as a continuing process " . . . indispensable for continued adaptability in a changing world . . . ;"
- availability of education, training, and retraining to individuals throughout their lives.

The Commission also proposed a nationwide system of public education lasting 14 years with direct links between high school curricula and those of community colleges and technical schools designed to prepare individuals for technical and paraprofessional careers.[12]

Education, Training, and Economic Growth

The concerns of the Automation Commission have reemerged in various forms. While the

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[10] *Technology and the American Economy: Report of the National Commission on Technology, Automation and Economic Progress,* vol. 1, February 1966.

[11] Ibid.

[12] Ibid, pp. 45-47.

Automation Commission's report focused on the role of education and training as a complement to technological change in stimulating national economic development, more recent studies focus on education and training and new technology as factors in regional, State, and local economic growth. A 1982 study published by the Northeast-Midwest Institute cites basic skills deficiencies as a critical problem already depressing economic growth rates in the Northeast and Midwest and threatening U.S. participation in international markets. That study recommends a unified policy for training, retraining, and skills upgrading for all workers.[13]

Other observations on the relationship between education, training, and economic growth are being made on the State level, as public and private groups explore the relationship of human resource development and continued economic advancement in their respective geographic areas. A Connecticut Business and Industry Association study has found that an appropriately trained work force is the strongest influence on location decisions of advanced technology companies and is critical to expanding that State's electronic economy. That study recommends: 1) diverting resources within Connecticut education institutions to programs that graduate individuals qualified to enter high technology industries, as well as 2) publicizing existing, in-State continuing education programs for working, corporate-based professionals.[14] Another study, conducted for the New York State Science and Technology Foundation, found that universities could participate in State economic development through cooperative university/industrial education programs, cooperative university/industry research and development programs and improved responsiveness to unique industry needs.[15]

In a series of recent papers on higher education and technological innovation, the New England Board of Higher Education responded to charges of unresponsiveness made by business leaders and others concerned about changes in occupational supply and demand by redefining the problem as a need on the part of educators for:

> . . . hard numbers on the regional supply of trained personnel, and correspondingly, projections of demand based on reasonably firm business plans . . . , a clearly assumed responsibility for the regular collection of such statistics and for the underwriting of expenses associated with continuing projects of this nature, (and) an organizational structure whose mission is to gain consensus from leaders of the business, education and governmental communities on the regional needs . . . and on the appropriate goals and strategies by which they can be attained. Plans for implementation would, ideally, include a clear demarcation between short- and long-term issues.[16]

Technological Literacy

It is possible that the United States is entering an era in which the potential for mechanization in the factory and the office will dramatically alter work force skill requirements. This will require employees and individuals preparing to enter the job market to enhance skills and/or to develop new ones. The OTA study, *Informational Technology and Its Impact on American Education,* found that in order to function as citizens in an information-based society that is driven in large part by technological innovation, individuals must have knowledge of the computer as a tool for managing and providing access to massive amounts of information. This need to understand the applications of computer technology has resulted in a modified definition of basic literacy that includes familiarity with the computer. "Technological literacy" is now a common term used to describe a level of understanding of technology in its various forms that goes beyond a familiarity with the computer. Experts suggest that technological literacy will soon be required of all members of the work force, as broader and more extensive applications of information technology are made in offices and plants. Widespread technological literacy may be hard to achieve, however, since about one-fifth of the U.S. population has yet to master the basic skills of reading, writing, and arithmetic.[17]

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[13] Pat Choate, *Retooling the American Work Force: Toward a National Training Strategy* (Washington, D.C.: Northeast-Midwest Institute, July 1982).

[14] Ann Wingate and H. Craig Leroy, *High Technology Industries and Future Jobs in Connecticut* (Business and Industry Association, December 1981), p. 10.

[15] *Special Report V: The Higher Education System in New York and Its Potential Role in Economic Development,* prepared for New York State Science and Technology Foundation by Battelle-Columbus Division, April 1982.

[16] "Engineering and Technological Education in New England—Part II: Alternatives for the Eighties," *Issues in Planning and Policymaking,* December 1981.

Industry representatives have expressed growing disillusionment with the lack of employability skills in entry-level workers with educational preparation through the graduate level. They define employability as an individual's understanding of the basic rules of the workplace, including the need to report for work, to arrive on time, to stay with a job for a reasonable period, and to demonstrate competence in the basic skills. This has led many companies to increase their involvement in education on the local and even national levels and to establish more in-house corporate education and training systems.[18] Labor unions and labor organizations have also been vocal in their concerns about basic skills deficiencies in those seeking apprenticeships. One union educational representative has found weak communications and reasoning skills common among trainees today. Many union locals establish close working relationships with school districts to improve basic skills, while national and international labor organizations address these problems by working with national education groups.

Although many elementary and secondary schools, both public and private, are placing renewed emphasis on basic skills development, and many adult education programs offer remedial courses in math, reading, and writing, these programs reach only some of the individuals who need this type of instruction. In addition, public school systems are hampered in modifying and strengthening curricula as a result of lower levels of Federal funding and reduced State and local tax revenues in many areas. These conditions complicate the process of developing strong basic skills and technological literacy among those preparing for entry into, and those already in, the work force.

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[17] "Ahead: A Nation of Illiterates?" *U.S. News and World Report,* May 17, 1982; National Center for Education Statistics.

[18] James Campbell, "Employers Expect the Best," reprinted from *Vocational Education Journal of the American Vocational Association,* vol. 55, No. 8, October 1981.

NEW TYPES OF INSTRUCTIONAL PROGRAMS

As a result of research performed to date, OTA has identified several instructional programs to prepare individuals to function in computer-automated manufacturing environments. It is too early to say whether or not the establishment of these programs constitutes the beginning of a trend, or to make qualitative evaluations, but the existence of these programs does indicate that some business, labor, and government representatives are aware of a skills gap in manufacturing firms where programmable automation has already been applied. It is important to note, however, that these programs are scattered; by no means do they constitute a coordinated attempt by the public and private sectors to address the problem of a potential widespread skills gap. At this stage in the investigation, it appears that the evolution of these and similar programs is occurring in traditional, uneven fashion, and that the capacities of educational institutions and other instructional providers would fall severely short of the potential demand for skills development and upgrading that may be associated with the widespread adoption of programmable automation.

Secondary-Level Programs

Since the establishment of a public education system, local school districts have attempted to develop secondary-level programs that achieve two distinct ends: 1) the preparation of some individuals for direct entry into the work force immediately after graduation; and 2) the preparation of others planning to enter college who require a strong foundation of knowledge on which to base more advanced instruction. Since lifelong learning is likely to become necessary for all members of the labor force, these objectives are becoming blurred. For example, in some high schools serving areas where programmable automation is now being produced or used in manufacturing, there are indications that students not going on to college are receiving more attention than in the past, and that career exploration for high technology careers is recognized as important for all students, regardless of their postgraduation plans.

The State of Michigan, due to its economic dependence on auto and truck manufacturing, has been hit hard by massive layoffs over the past few years. With high unemployment among manufacturing workers in the region, some local high schools in southeastern Michigan have been looking for new career opportunities for which they can begin to prepare their students.

Several Michigan school systems, including Oakland County, have added introductory robotics courses to their curricula. These courses give students an opportunity to learn first-hand about robotics technology and to explore career opportunities within this manufacturing-related field. Students learn to operate simple, tabletop, electric robots, which are provided to the school systems by local robot manufacturers, or build their own robots. In some cases, courses include site visits to local auto manufacturing plants to observe robot applications in welding and painting. There are no prerequisites for juniors and seniors who wish to enroll. It is important to note that these courses do not purport to develop entry-level job skills in students, but are offered simply as an opportunity to develop some measure of career awareness in high technology. Also, there are no formal placement services provided and at present no links to more advanced robotics technology instruction.

An experiment is underway in Oakland County, where segments of a successful summer high school robotics course have been incorporated into the curricula of several regional vocational-technical centers. Courses offered through these centers are open to high school students as well as adults who wish to explore interests and career options in the field of robotics.

Retraining for Skilled and Semiskilled Occupations

Unions and others concerned about the potential social impacts of the use of programmable automation have been active in promoting the need for retraining programs for skilled and semiskilled occupations. They regard education and training as tools for strengthening the job security of and alternative job opportunities for their members. Through collective bargaining and other means, unions are looking for ways to influence who is trained and what is taught in retraining programs. In particular, unions are looking at ways to have more control over in-plant training to upgrade skills and to modify standard tuition refund programs to provide members with more opportunities to participate in education and training programs outside the workplace.[19] This position is in keeping with provisions included in selected agreements of the 1960's, when earlier forms of manufacturing automation were applied in steel, electronics, and aerospace firms.[20]

The United Auto Workers (UAW) and the International Association of Machinists (IAM) are among the most active unions in promoting technology-related education, training, and retraining opportunities for their respective memberships. Within 1982 agreements UAW reached with Ford Motor Co., General Motors, and International Harvester, there are provisions for training and retraining programs for current employees as well as those laid off. In addition, each contract calls for the establishment of a joint union-management employee development and training committee through which special instructional assistance will be provided to members who are displaced by new technologies, new techniques of production and " . . . shifts in customer preference." Employees—both skilled and semiskilled—are covered under other provisions of the agreements. They are eligible to participate in upgrade training designed to sharpen job skills and to provide updates on the state of the art of technology being utilized in their plants.[21] [22] [23]

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[19] "Retraining: The Need for Flexibility," in *Silicon, Satellites and Robots: The Impacts of Technological Change on the Workplace* (Washington, D.C.: Department for Professional Employees, AFL-CIO, 1979), pp. 44-45.

[20] See *Recent Collective Bargaining and Technological Change* (Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics, March 1964), BLS Report No. 266.

[21] "Programs Set Up for Training and Retraining," *UAW-GM Report*, March 1982, p. 11.

[22] "Training, Retraining Plan to Cover Ford Workers," *UAW-Ford Report*, February 1982, p. 7.

[23] *UAW-International Harvester: Highlights of the New Agreement-1982-1984* (Detroit, Mich.: UAW Agricultural Implement Department, April 1982).

The Ford agreement called for the establishment of a National Development and Training Center, where staff on loan from the union and the company will promote training, retraining, and other skills development opportunities for current and displaced workers.* Two projects were launched by the Center in August 1982: a National Vocational Retraining Assistance Plan, which provides prepaid financial assistance of up to $1,000 per year to workers on layoff who wish to undertake self-directed, formal education or retraining; and Targeted Vocational Retraining Projects, highly specialized retraining activities designed to develop skills for use in new or existing occupations in which there are documented worker shortages. The Vocational Retraining Projects would be limited to geographic areas where established educational institutions and vocational training programs are not already providing such instructional opportunities. The Center also hopes to stimulate similar, publicly funded efforts in areas of the country where Ford workers are on layoff and might be eligible to participate.[24]

IAM initiated in the 1950's an annual electronics industry conference, known since 1968 as the Electronics and New Technology Conference, during which national staff and representatives of IAM union locals discuss issues that arise from the use of manufacturing technologies. In 1960, IAM began the practice of preparing a manual of model contract language that included provisions for use in dealing with in-plant technological change. IAM model contract language on training benefits calls for instruction during working hours at company expense and at prevailing wage rates. It also states that senior employees should have first claim on training opportunities and suggests that management should be required to train employees for jobs not necessarily associated with new technology, in cases where " . . . either the new technology requires substantially fewer workers or present employees are not capable of successful retraining."[25] At an IAM-sponsored Scientists and Engineers Conference, held in the union's Placid Harbor Training Center in June 1982, members expressed concern that training and retraining provisions in contracts address instructional procedures as well as content.

Retraining the Displaced

A comprehensive review of documentation representing over 20 years of plant-closing experience revealed that retraining programs are of greater benefit to displaced workers who are younger, have slightly more formal education, and have achieved some level of financial security. Even among displaced individuals who possessed these characteristics, only about 15 percent participated in retraining, due to inadequate financial assistance during the training period.[26] These findings suggest that some new approaches to retraining the displaced should be developed that increase the utility of instruction and its availability to workers of all ages, with varying amounts of formal education and different degrees of financial security.

Although the public perception is that industry is one of the chief sources of sponsorship for retraining of displaced workers, in the past it has sponsored few retraining efforts. In some cases, the communities surrounding plants lacked alternative career opportunities for which instruction could be provided; in others, workers expected to be called back to their old jobs and resisted taking advantage of instructional and placement opportunities; in still other cases, economic conditions that led a company to close a plant made the cost of retraining prohibitive. Although retraining activities authorized under the Comprehensive Employment and Training Act (CETA) and the Trade Readjustment Assistance Act (TRA) have been criticized, these Federal programs represent the majority of resources that have been utilized to prepare displaced workers for new careers.*

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*The Center, temporarily located at Ford World Headquarters in Dearborn, Mich., will move to its permanent headquarters at Henry Ford Community College (Dearborn) in 1983.

[24] "National Vocational Retraining Assistance Plan and Other Projects for Certain Employees on Layoff," *UAW-Ford Employee Development and Training Program Bulletin,* Aug. 20, 1982.

[25] Leslie E. Nulty, "Case Studies of IAM Local Experiences With the Introduction of New Technologies," in *Labor and Technology: Union Responses to Changing Environments* (University Park, Pa.: Department of Labor Studies, Pennsylvania State University, 1982), pp. 115-139.

[26] Jeanne P. Gordus, Paul Jarley, and Louis A. Ferman, *Plant Closings and Economic Dislocation* (Kalamazoo, Mich.: W. E. Upjohn Institute for Employment Research, 1981).

Two recent examples of retraining efforts funded under CETA illustrate the potential for retraining some of the displaced for new, technology-related occupations. The first, a pilot project made possible through a $300,000 Department of Labor discretionary grant to UAW, is designed to retrain 400 displaced auto workers for occupations in demand within the aerospace/defense industry. The first phase of the project, an assessment of the potential for skills transfer from jobs performed within the auto industry to the new positions within aerospace/defense, has already been completed. Other products of the grant include two retraining programs, which will be developed by combining components of existing retraining packages.[27] Although the project does not train individuals solely for technology-related positions, a UAW spokesperson indicated that many of the new aerospace jobs involve working with automated equipment and therefore related skills requirements will be addressed in the retraining packages to be developed. Implementation of the training process now awaits Federal funding or sponsorship by the aerospace/defense industry. A second CETA-funded project, initiated by the Warren County, Mich., prime sponsor, is a 40-week robotic technician program, which qualifies 18 displaced auto workers, machinists, and others who completed the course to assume new careers within the auto industry, in local robotics firms, or in other companies using robots.**

Instruction for Technician-Level Occupations

Although technicians emerged as an occupational group within the field of engineering in the 1920's, the availability and application of technology in manufacturing has increased the demand for and the popularity of this occupation. Technicians who are trained in the use of computer-aided drafting systems are now in great demand within aerospace and other industries.[28] Technician instruction is typically a 2-year associate degree program, although other, more concentrated approaches to program delivery are becoming more common, such as the one initiated in Warren County, Mich. The electromechanical technician curriculum, which combines two formerly distinct engineering specialties, is viewed by some educators and industry representatives as an excellent foundation for careers that require knowledge of programmable automation.

Community colleges in various areas of the country are currently offering electromechanical technician programs, sometimes called robotics technician programs by the institutions in order to capitalize on general public awareness of this form of programmable automation. The State of Georgia began offering an electromechanical curriculum in its community colleges in 1982. Several community colleges in Michigan have offered electromechanical programs for the past few years. In general, curricula are designed to prepare enrollees to perform installation, maintenance, repair, and programing functions. At present, however, no standardized performance criteria exist for electromechanical technicians, so the content and emphasis of these programs vary considerably.

Engineering Education

The utilization of programmable automation has had an observable effect on initial and continuing education for engineers. CAD, which enables faster design and analysis, is now common in the aerospace and auto industries. Selected engineering schools are working with industry to

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*The recently enacted Job Training Partnership Act, which replaces CETA, authorizes the expenditure of Federal funds for employment and training of dislocated workers. CETA will operate during fiscal year 1983 at a $2.8 billion funding level, while programs authorized under the Training Partnership Act are established (*Employment and Training Reporter*, Nov. 19, 1982).

[27] "Assessment of the Reemployment Opportunities for Unemployed Automobile Workers in the Aerospace/Defense Industry," proposal prepared for the U.S. Department of Labor by the United Auto Workers, 1982.

**As stipulated in Public Law 95-524, CETA amendments of 1978, a prime sponsor may be ". . . a State; a unit of general local government which has a population of 100,000 or more . . . ; a consortium of units of general local government . . . ; . . . program grantees serving rural areas having a high level of unemployment . . . ; and any unit of general local government previously designated as a prime sponsor under the provisions of this Act . . . , regardless of population decline."

[28] "The Engineering of a Revolution: Computer Now Designer's Tool," *The Atlanta Constitution*, Oct. 24, 1982.

add CAD instruction to their curricula. Boeing Commercial Airplane Co. in Seattle, Wash., has established at the request of local universities (e.g., Washington State) CAD laboratories adjacent to engineering school campuses. These labs provide students with opportunities to work with Boeing aircraft data bases when they are not being utilized by Boeing personnel. The program is voluntary, but students receive university credit for participating.

On the national level, a 1981 grant from the National Science Foundation's Directorate for Science and Engineering Education (now the Office for Science and Engineering Education) established the College CAD/CAM Consortium as a nonprofit group dedicated to the development of CAD/CAM curriculum and the improvement of CAD/CAM instruction. Twelve engineering schools, including Carnegie-Mellon University and Rensselaer Polytechnic Institute, were founding members.[29]

SURVEY OF CURRENT VIEWS OF EDUCATION, TRAINING, AND RETRAINING REQUIREMENTS

There has been little or no information gathered on how representatives of the key groups involved in or affected by the manufacturing automation process—producers of the equipment and systems; users of the equipment and systems; and various groups in the work force—view the potential retooling of the operations with which they are associated. In addition, no national readings have been taken of current views held by these groups on education, training, and retraining requirements associated with the use of programmable automation. In order to supplement available information of this type, and in so doing get a better sense of the climate in which automation is occurring, OTA commissioned structured telephone interviews with a sample of representatives of firms within the electric and electronics equipment, industrial machinery, and transportation equipment industries (industries in which firms are especially likely to use programmable automation). OTA also contacted producers of programmable automation equipment and systems, as well as educators and others familiar with the instructional design process. A total of 506 interviews were completed in July and August 1982.* In this section of the technical memorandum, a summary of selected survey findings is presented. A description of the survey methodology and sample size are included in appendix A.

Education and Training: Users and Producers

The survey found that 40 percent of the representative manufacturing plants contacted utilized some form of programmable automation, and of this number, only 22 percent sponsored or conducted education and training for new technology. Among plants currently not offering education and training of this type, only 18 percent indicated any plans to implement programs in the future. Low benefits relative to costs was by far most commonly cited by user firm representatives as a barrier to the establishment of instructional programs for new technology. The low levels of current and anticipated direct involvement in education and training for new technology is particularly notable in light of the nearly unanimous view expressed by users, producers, and others that the users should bear the costs for new technology instruction. This seems to indicate that while users may be willing to pay for instruction delivered by vendors, educational institutions, and others, few are planning to establish their own, in-house programs. Another possible interpretation of the low levels of in-house instruction among users might be that changes brought about through the utilization of programmable automation thus far have not been sufficient to warrant the establishment of formal instructional systems.

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[29] *The College CAD/CAM Consortium: An Overview* (Charlottesville, Va.: University of Virginia, School of Engineering and Applied Science, January 1981).

*The term *users* refers to firms applying programmable automation; the term *producers* refers to firms producing programmable automation; and the term *others* refers to educators and others involved with education and training.

Instruction Available Through Producers

In contrast to the low proportion of users who sponsored and conducted education and training for new technology, a very high proportion of producers (93 percent) provide such instruction for their customers. Manufacturers within the industry groups polled appeared to depend on producers for design and delivery of new technology-related instruction. Results indicate that vendors or producers of programmable automation equipment were more heavily used for instruction than were training industry/management consultants, traditional educational institutions, proprietary schools, unions, and government-sponsored instructional programs such as CETA.

The nature and scope of instruction currently offered by producers, however, seems to be quite limited. Over 80 percent provide only single courses, and few provide series of courses. Furthermore, only about one-third of the producers felt that vendors or manufacturers of computer-automated equipment and systems were currently ready to provide the necessary education and training. One can speculate that the producers who work closely with new technology understand the education and training implications of implementing their technology, but are currently only providing part of what they consider is required. Producers may be providing limited services for a variety of other reasons, including cost factors, customer demand, and their views of the responsibilities of other institutions (particularly users) in providing additional training.

Occupational Coverage and Content Coverage

Both users and producers reported generally broad occupational coverage in the instructional programs on new technology that they provided, although there was considerable variation in the extent to which occupations were covered. The majority of both users and producers sponsored or conducted programs for various types of shop-floor staff (e.g., assemblers, handlers, loaders, equipment operators), repair and maintenance staff, engineers, programers, and supervisors or managers. Apparently, the impact of programmable automation on a wide array of occupations is recognized by industry.

Broad occupational coverage was not accompanied by breadth in instructional content. The primary content of current education and training programs appears to reflect traditional topics addressed in technical training; e.g., machine operation, safety procedures, and maintenance. Current instructional programs focus least on the basic skills—reading, writing, and arithmetic—and basic physical science. The survey results suggest that manufacturers assume that these needs should be met in ways other than in instructional programs they devise.

Government Role in New Technology Instruction

Survey results show a lack of receptivity to government involvement in instruction for new technology by both users and producers. As noted earlier, government-sponsored instructional systems such as CETA were generally considered not ready to provide such training and were not expected to become ready within 10 years. When asked about possible sources of funding for education and training for new technology, only about half of the respondents in both groups indicated that Federal or State and local government funding was desirable, while funding from all other sources, particularly private sector user industries and foundations, was endorsed by at least three quarters of the respondents. In contrast, a great majority of the others (the group that included educators and Federal and State officials) endorsed government as a funding source.*

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*It is not clear whether these responses reflect popular political views, attitudes toward government intervention in general, or actual preferences for private control of instruction for high technology. In any case, it is unlikely that respondents had in mind all forms of Federal, State, or local support (e.g., funding of colleges, universities, and research efforts), although it is not possible to determine this from the present data. Nevertheless, the consistency of responses in the user and producer groups may provide some guidance for determining the nature of the government role in instruction for computer-automated manufacturing. It is likely that indirect or less visible forms of government intervention would be more acceptable to industry than more direct forms of intervention, such as the provision of education and training services (e.g., CETA programs) or direct subsidies to industry for worker retraining.

SELECTED CRITICAL ISSUES FOR INSTRUCTIONAL PROGRAMING

Current views of representatives from industry, labor, the educational community and government are consistent with other indicators discussed earlier in this technical memorandum in suggesting that training and retraining requirements for programmable automation are, at this point, poorly defined. Even within specific geographic areas, programs initiated to address changing instructional requirements do not in the aggregate represent a coordinated approach to defining instructional needs associated with new industrial processes. While it is too soon to know how widespread applications of programmable automation will be, there is little evidence that any sector—including private industry—is seriously considering the long-range implications of possible widespread use on occupational skills requirements and current instructional capacities.

There are a number of pressing issues facing those who operate instructional systems, in the event that widespread utilization of programmable automation occurs. Among them are:

1. how and by whom the need for technological literacy will be addressed,
2. types of short-range and long-term counseling and instructional systems,
3. initiation of appropriate curriculum design processes, and
4. funding sources for curriculum design and implementation.

Appendixes

Appendix A
Survey Methodology

Introduction and Overview

In support of the Automation and the Workplace study undertaken by the congressional Office of Technology Assessment, Westat conducted a survey to identify education and training requirements inherent in the use of programmable automation in manufacturing settings. The survey describes current levels of utilization of programmable automation, as well as existing instructional opportunities focused on this form of technology, and elicits various opinions related to current and anticipated education and training needs resulting from applications of computer-based automation.

Survey data were collected by the Westat Telephone Research Center on three samples: 1) users, 2) producers of computer-automated technologies in manufacturing, and 3) a diverse sample of knowledgeable others. The surveys used structured instruments developed for the study. Data were collected by telephone interviews over a 2-week period in August 1982.

Methodology

This section briefly describes the methodology used for the survey. The first part describes sampling procedures, the second describes data collection instruments and methdology, and the third describes data analysis procedures.

Sample

Three groups were contacted for this study: users and producers of computer-automated equipment and systems, and others, a diverse group of individuals involved in instruction for employees in computer-automated manufacturing environments or for individuals preparing for careers in such settings. Formal sampling procedures were used only for the user group, and for a subset of the others. Details of the procedures are described below.

USERS

Sampling Frame.—The sample of users was composed of manufacturing establishments from industries identified as currently using or likely to use computer-programmable equipment and systems in the near future. An establishment was defined as an individual location of company. This location might constitute a division, subsidiary, plant, branch, or the entire company.

Three major manufacturing industries were represented: transportation equipment manufacturing, electric and electronic equipment manufacturing, and industrial and metalworking machinery manufacturing. For each of these three major industries, specific standard industrial classifications (SIC) were selected based on two criteria: 1) proportion of total employees in industry accounted for by establishments within the SIC code; and 2) likelihood of establishments within the SIC code using computer-automated technology. SIC codes meeting the second criteria were selected based on judgments of project staff, as well as OTA Automation Study Advisory Panel members. The selected SIC codes for the transportation equipment industry account for 76 percent of the total workers employed in the industry; SIC codes in electric and electronic equipment manufacturing account for 59 percent of the total employees; and the SIC codes in industrial and metalworking machinery account for 41 percent.

The data source for constructing the frames for the three user samples was National Business Lists (NBL), a firm which compiles a national list of most types of establishments, including manufacturing and commercial. The NBL lists rely heavily on the Dun & Bradstreet directory of establishments, supplemented by NBL's own sources.

Sampling Methodology.—A probability sample of users in the three industries was selected from the NBL lists using a two-stage sampling approach. This sampling procedure involved stratification by size and regional location, and included as selections with certainty a small number of establishments known to use computer-automated equipment for manufacturing. These were included to assure a minimum of current users within the sample to provide an adequate basis for analysis of this subgroup.

The first step in a two-stage sampling procedure entailed compiling a list of approximately 5,000 establishments from the NBL master file in the three major industry groups specified earlier. The purpose of "oversampling" establishments at this initial stage was to obtain a sufficiently large sample for examining the size distribution of establishment by SIC group for subsequent use in deriving appropriate (and more nearly optimal) sampling rates. Since larger establishments account for a larger share of the work force while accounting for a smaller share of the total number of establishments, selection of the initial sample from NBL was stratified by establishment size. The size strata used by the initial sampling were:

Small:	1-99 employees
Medium:	100-499 employees
Large:	500 or more employees

Furthermore, to take these size differences into account in the sampling, large establishments were sampled at a higher rate than small ones. Therefore, the initial sample consisted of *all* of the large establishments in NBL for each of the three industries, *one-half* of the medium-sized establishments and *one-tenth* of the small establishments. Since the listings of establishments in the NBL file were geographically sorted within each of the three size classes, and the samples were selected systematically (using a random start), the method of sample selection simplicity included stratification by geographic region. These proportions yielded 5,128 total establishments in the initial sample.

In the second stage of the sampling procedure, the 5,128 establishments were further stratified by industry type, establishment size, and regional location. Regional location was defined by the four regions delineated by the U.S. Census Bureau (i.e., Northeast, North Central, West, and South). In addition to the three major size strata defined above, the "small" size class was further subdivided into two classes for sampling (1-20 and 20-99). This more detailed stratification by size permitted a more nearly optional allocation of the sample cases to the various strata. This stratification yielded 48 different cells in which establishments were placed for sampling.

To determine the appropriate sampling rates to select the second-stage sample, three options were considered:

1. The sample could be allocated to each cell in proportion to the total number of establishments in that cell.
2. The samples could be allocated to each cell in proportion to the total employment in that cell.
3. The samples could be allocated to each cell in proportion to some function of employment, say square root of employment.

The implication of the first option was to have large numbers of small establishments and few large establishments since most manufacturing establishments have fewer than 500 employees. This would be desirable for estimation of counts of establishments, but would not be sufficient for estimation of magnitude variables such as employment.

The implication of the second option was to have large numbers of large establishments and very few small establishments, since manufacturing establishments of 500 or more employees account for most of the work force. This would be approximately optimum for estimation of magnitude variables (in particular, those correlated with employment), but would be less efficient for estimates of the numbers of establishments.

The final option, which combines the first and second options by sampling with probabilities proportionate to the square root of employment, distributes the numbers of establishments somewhat more evenly across cells. This last option was selected because it provided a better basis for making comparisons between the different size classes, in addition to being reasonably efficient for estimating both magnitude and count variables.

Sampling Methodology.—Establishments from the user sampling frame were screened to eliminate from the user samples those not meeting the following criteria:

1. establishments must be performing manufacturing functions at the location contacted (purely administrative facilities were dropped); and
2. establishments must be able to identify an individual within the first three referrals during the phone call who can answer selected key questions. (Those unable to do so were treated as nonresponses.)

Selection of the second-stage sample, therefore, was based on the assumption that there would be extensive dropouts due to ineligibility and nonresponse. From the initial sample of 5,000 user establishments, 200 establishments were drawn from each user industry group for a total of 600 sample establishments. These were allocated to the various size strata in proportion to the aggregate measure of size based on the square root of employment. This sample included 18 establishments that were selected with certainty in addition to the 600 selected establishments. The sample allocation of the noncertainties in each user industry group by size class is shown in table A-1.

Detailed records were kept of establishments failing to meet these criteria as well as refusals and nonresponses. Table A-2 shows the distribution of the initially sampled cases and the final number of completed interviews by size strata and region.

PRODUCERS

Sampling Methodology.—The producer group was composed of companies who manufacture and/or sell programmable equipment to U.S. manufacturing industries. The compilation of a list of producer companies was no simple task, since no such lists were readily available. An intensive search to identify com-

Table A-1.—Sample Allocation for User Groups

Size class (employment)	Number of establishments in NBL	MOS[a] based on square root of employment	Sample allocation
Transportation equipment			
1-19	2,070	5,430	30
20-99	1,030	7,050	40
100-499	596	9,020	50
500+	287	14,969	80
Total	3,983	36,469	200
Electrical and electronic machinery			
1-19	4,520	11,440	40
20-99	2,090	14,510	50
100-499	1,244	18,742	60
500+	363	14,240	50
Total	8,217	58,932	200
Machinery manufacturers			
1-19	12,620	30,900	60
20-99	3,590	22,450	50
100-499	1,296	19,092	50
500+	318	12,005	40
Total	17,824	84,447	200

[a] Measure-of-size: For a given size class, the aggregate MOS was computed as $S = \frac{N}{2} E_i$, where E_i is the average employment size of all establishments in the SIC group and size class based on 1979 *County Business Patterns*, and where the summation extends over all establishments in the NBL frame.

SOURCE: Westat.

Table A-2.—Stratification of User Establishments and Costs of Initially Sampled Cases and Completed Interviews[a]

	Northeast	North Central	South	West
Transportation region				
1-19	4 : 2	8 : 1	6 : 1	12 : 4
20-99	8 : 4	14 : 8	6 : 3	12 : 4
100-499	8 : 3	26 : 16	8 : 8	8 : 2
500 or more	12 : 6	42 : 24	16 : 11	10 : 6
Electrical/electronic region				
1-19	12 : 3	8 : 3	8 : 4	12 : 4
20-99	18 : 9	10 : 4	8 : 4	14 : 8
100-499	22 : 11	14 : 7	12 : 4	12 : 7
500 or more	16 : 9	12 : 8	10 : 6	12 : 6
Machinery region				
1-19	12 : 5	28 : 13	10 : 4	10 : 3
20-99	10 : 5	28 : 9	10 : 8	6 : 2
100-499	10 : 5	26 : 10	10 : 3	4 : 1
500 or more	8 : 7	20 : 12	8 : 6	4 : 1

[a] The number on the left in each cell shows the initial sample count, and the number on the right shows the number of completed interviews. The number of completed interviews shown in this table does not include the nine completed users which were sampled with certainty, since these were not preassigned to a size class.

SOURCE: Westat.

panies who were involved in manufacturing or selling computer-automated equipment was conducted by OTA, with assistance from Westat & Hadron, a subcontractor. The list used in this study was constructed from a variety of sources, including rosters of exhibitors at conventions on computer-automated manufacturing, lists from organizations such as the Robotics Institute of America, trade publications citing companies involved with such products, and personal contacts with relevant companies. The final list consisted of 203 producers, and is considered to be a fairly good approximation of the actual universe of companies producing computer-automated equipment for manufacturing in the United States.

Producers were contacted in random order until 101 companies had completed interviews.

OTHERS

Sampling Frame.—The others group was composed of individuals who have had experience in designing and/or delivering and/or evaluating formal instruction for employees operating in computer-automated or conventional manufacturing environments. These others were selected because of their pertinent expertise and/or because they represented institutions (e.g., unions) whose opinions are important to consider in formulating policy in this area. A list of 280 others was compiled by OTA. The list was composed of six subgroups:

- traditional educational institutions (e.g., colleges and universities, community colleges, technical schools);
- proprietary educational institutions (private, profitseeking, trade and technical schools that operate on the secondary and postsecondary level);

- labor unions and labor organizations;
- training industry representatives (individual consultants and training firm representatives);
- State and local agency representatives (e.g., vocational education and economic development agencies); and
- miscellaneous others (e.g., Federal Government and trade association representatives, individual scholars, and experts).

Sampling Methodology.—Representatives of traditional educational institutions were randomly sampled, while attempts were made to contact all those in the other five subgroups. The initial goal of obtaining 25 interviews from the traditional education subgroup and 75 from the remaining subgroups had to be revised, due to nonresponse rates among the five other subgroups. Actual portions are presented below.

Final Samples and Response Rates

A total of 506 interviews were completed for the study. There were 303 users (105 in transportation equipment, 98 in electric and electronic equipment, and 100 in industrial and metalworking machinery), 101 producers, and 102 others. In the others sample, there were 34 traditional educators, 11 educators from proprietary educational institutions, 13 union representatives, 2 representatives of the training industry, 17 representatives of State and local agencies, and 25 "others."

The response rates obtained (defined as the number of completed interviews plus refusals) were 82 percent overall, 76 percent for the users, 89 percent for the producers, and 95 percent for the others. The completion rates (defined as the number of completed interviews divided by all completes plus all incompletes) were somewhat lower, due to unknowledgeable, unavailable, or nonlocatable respondents. Table A-3 summarizes the final completion status of the telephone surveys conducted with further explanations of various completion statuses in table A-4.

Data Collection Instruments and Methodology

SURVEY INSTRUMENTS

Three telephone survey instruments (for users, producers, and others) were developed for the study. The instruments were closed-ended in format—i.e., response options were provided for most of the questions. A core set of questions was asked three groups, along with additional questions designed specifically for each group. The instruments were designed to require approximately 15 to 20 minutes per interview.

In general, the instruments were designed to obtain information about the extent and nature of the involvement of the respondents with programmable automation technology, their involvement with education and training focused on the application of various forms of programmable automation in manufacturing settings, and their opinions about a variety of issues related to such instruction. In addition, questions on basic background characteristics (e.g., size of the work force) were also included in the instruments.

Table A-5 presents the major topics covered by the three survey instruments. The greatest number of questions were asked of the users, although most topics were covered in the three instruments. One major dif-

Table A-3.—Final Response and Completion, Statuses of Telephone Surveys

	Users						
Status codes	Group 1	Group 2	Group 3	All users	Producers	Others	Total survey sample
Complete	105	98	100	303	101	102	506
Admin Hdqtrs	32	21	22	75	1	—	76
Not working	11	9	11	31	11	—	42
No answer	1	11	12	24	—	—	24
No new tech	—	—	—	—	39	—	39
No E&T	—	—	—	—	—	3	3
Duplicate	1	2	—	3	7	7	17
Final refusal	31	28	35	94	12	5	111
Not available	11	13	13	37	23	14	74
Not locatable	—	21	14	35	9	5	49
E&T knowledge	—	1	—	1	—	—	1
Response rates[a]	77%	78%	74%	76%	89%	95%	82%
Completion rates[b]	71%	61%	62%	65%	70%	81%	68%

[a] $$\text{Response rate} = \frac{\text{No. completes}}{(\text{No. completes}) + (\text{No. final refusals})} \times 100$$

[b] $$\text{Completion rate} = \frac{\text{No. completes}}{(\text{No. completes}) + (\text{No. noncompletes})} \times 100$$

SOURCE: Westat.

Table A-4.—Definitions of Completion, Ineligible, and Nonresponse Status Codes

I. **Completion**
  - A. *Complete* (C)—completed entire interview. A complete means all pertinent questions have been answered.

II. **Ineligibility** (The following categories of respondents were screened out of the survey.)
  - A. *Admin hdqtrs* (I)—user establishment is an administrative headquarters which does not perform a manufacturing function.
  - B. *Not working* (NW)—phone number is not in service and, after calling directory assistance, there is no new listing for that facility.
  - C. *No answer* (NA)—there is no answer after three attempts at different times on different days.
  - D. *No new tech* (NL)—producers only; if producer establishment is not manufacturing or selling new technology included in the survey.
  - E. *No E&T* (S2)—others only; if respondent represents a traditional educational institution, proprietary educational institution, or a training firm, which does not have an education and training program.
  - F. *Duplicate* (OA)—duplicate respondent.

III. **Noncompletion** (The following categories of respondents are included in computation of a completion rate.)
  - A. *Final refusal* (RB)—respondent refuses the interview or breaks off interview.
  - B. *Not available* (O)—respondent was not available during field period.
  - C. *Not locatable* (S1)—appropriate respondent was not located after three referrals or the respondent was not knowledgeable about new technology for his/her establishment.

SOURCE: Westat.

ference should be noted in the questions on education and training in the three instruments. Users were asked about the education and training provided to their own employees. In contrast, producers and others were asked about the instruction they provide to customers or clientele, not their own staff.

The instruments were developed in several stages by Westat & Hadron staff, in collaboration with OTA. At the start of the reseach effort, 12 in-depth interviews were conducted, in person and on the telephone by Westat & Hadron staff, to identify important issues and develop possible questions and response options for the instrument. A topic guide was developed for these interviews.

Based on these preliminary interviews, a list of draft questions and response options was submitted to OTA. Comments from OTA staff and further interviews by Westat & Hadron staff were used to refine and shorten the questionnaires.

The instruments were pretested by the Westat Telephone Center on a small number of respondents, and further minor changes resulted from the pretests.

Data Analysis

SAMPLE WEIGHTS

Since disproportionate sampling procedures were employed in drawing the user samples—i.e., different sampling ratios were used for the different strata—

Table A-5.—Topics in Survey Instruments

	User	Producer	Other
Background			
• Year founded	X	X	X
• Gross sales	X	X	X
• Work force or clientele characteristics	X	X	X
Computer automation			
• Use, production, or sale of new technologies	X	X	
• Extent of computerization	X		
• Computerized integration of equipment	X		
Education and training (E&T)			
• Presence of general E&T, and E&T for new technology	X	X	X
• Priority given to setting up E&T	X	X	X
• Barriers to setting up new technology instruction	X	X	X
• Work force/clientele percentage who received or will need E&T	X		X
• Number of instructors for new technology	X	X	X
• Forms of instruction	X	X	X
• Sources for designing/delivering instruction	X		
• Target occupational groups	X	X	X
• Skill and knowledge areas covered	X	X	X
• Policies and opportunities on E&T outside the company	X		
Opinions			
• Current and future readiness of institutions to provide instruction	X	X	X
• Options for institutional collaboration on E&T	X	X	X
• Sources of funding for E&T	X	X	X

SOURCE: Westat.

mechanisms to equalize the differential probabilities of selection attached to establishments from the different strata were required. Such weighting adjustments are necessary in cases where generalizations are made from the sample to a larger sampling frame or universe, and to take into account nonresponse.

Weights were applied only to the user sample and the others. Weights were not necessary for the producers, since they did not constitute a sample from a larger universe of such firms. Users were given weights such that the sample represented an estimated 24,142 active and eligible establishments in the NBL frame—and the other sample was weighted to represent the 280 others in the original sampling list. The estimated 24,142 active and eligible user establishments was obtained by summing up the weights of the responding establishments in the sample and compares with about 30,000 establishments in the designated SIC groups in the NBL frame.

The sampling weights for the OTA samples (user and other groups) were computed from the formula: where

W_{hi} = The weight for establishment i in stratum h (for a particular group).
n_h = The total number of establishments (in the frame) in stratum h.
N_h = The number of establishments in stratum h that were finally sampled.
n'_h = The number of eligible and responding establishments in stratum h.
n''_h = The number of eligible but nonresponding establishments in stratum h.

The factor, $(n'_h + n''_h)/n'_h$, in the above expression represents an upward adjustment for total questionnaire nonresponse. The weight for any given establishment depends on the stratum (and group) from which the establishment was sampled, but is uniform for all responding establishments in a particular stratum. Weights for the establishments selected with certainty would be 1.0 if there were no nonresponding cases, and otherwise exceed 1.0 by a factor representing an adjustment for nonresponse.

Table A-6.—Sampling Weights for Estimation

	Sampling stratum				
Respondent group	Certainty	< 20 employees	20-99 employees	100-499 employees	500+ employees
User 1 (transportation)	2.5	155.2	42.8	18.4	4.8
User 2 (electric and electronic)	4.0	248.4	74.5	36.1	10.0
User 3 (industrial and metalworking)	1.0	419.0	136.6	52.2	10.3
Others	1.2	Noncertainties[a]: 4.7			

[a] As indicated in "Others" section in text, all traditional educators except for educational institutions were included in the sample with certainty. Educational institutions were sampled at a fixed rate of about 1 prior to adjustments for nonresponse.

SOURCE: Westat.

Appendix B
Industrial Relations

Overview

The activities, institutions, and circumstances of industrial, or labor-management, relations influence the implementation of new technology and its consequences within firms and industries. In particular, they contribute to employment patterns and workplace conditions that might not arise with technology change and market forces alone. Therefore, an understanding of industrial relations is necessary for understanding not only how programmable automation may affect company and industry employment and wage levels; but also how job content, promotion paths, and workplace conditions may change with programmable automation; and why employees and management in different companies and industries may have different experiences with technological change.

Despite the important role of industrial relations in the U.S. economy, the analysis of industrial relations tends to be relatively imprecise and experiential. As one participant in the OTA Labor Markets and Industrial Relations Workshop put it, there seem to be more "ad hoc-eries" than true theories for explaining industrial relations phenomena. Further complicating an evaluation of industrial relations issues are the differences in approach taken by different analysts. For example, most labor economists and so-called industrial relationists tend to regard workers and managers as having opposing interests, with workers striving to minimize work effort and maximize compensation, and managers striving to minimize cost and maximize production. Most organizational behaviorists and organizational development specialists tend, by contrast, to regard workers and managers as sharing basically similar interests that stem from their association with the same organizations. The former group tends to focus on the setting of wages and other "economic" issues, while the latter group tends to focus on job satisfaction and performance, supervisory relationships, and job design.[1]

A final, but critical, factor complicating attempts at precise analysis of industrial relations issues is the fact that rhetoric that tends to exaggerate conflict between labor and management can obscure the actual circumstances of industrial relations, particularly in unionized settings. According to some observers, rhetorical hostility between organized labor and management has been especially high during the last few years:

> . . . (W)e are witnessing a continuation of this recent high level of rhetorical hostility between labor and management compared to the situation that prevailed during most of the 1950-80 period. In addition, . . . the onesidedness of our (and the traditional) definition of conflict as *worker* action shows a tendency to obfuscate the reality of conflict between managers and workers, for it leads us to reject aggressive action by management.[2]

This rhetoric, amplified by the news media in the context of deteriorating economic conditions, may bias public opinion against organized labor, despite the lack of objective analysis of the contributions of both labor and management activities to current economic conditions.

The popular, and even the research, view of industrial relations tends to focus on unionized settings, since unions (and employee associations that function similarly) serve to focus and articulate the concerns of workers both at the workplace and in the community, although only a portion of U.S. companies and workers are unionized. The union-nonunion distinction is misleading, however, because labor-management relations fall into a spectrum that includes intermediate arrangements containing greater and lesser numbers of pure union-like and nonunion-like attributes. The principal difference between the union and the nonunion setting is that in the nonunion setting, management typically imposes job descriptions, wage levels, working conditions, and technological change unilaterally, while in the union setting, many of the terms of the workplace are jointly set by labor and management through a negotiation process. Therefore, the role or conduct of labor is as important as that of management in the unionized setting.

Unions are of particular, but not exclusive, interest to a study of the impacts of programmable automation because workers in many of the occupations and industries where programmable automation is expected to have the greatest impacts are especially likely to belong to unions. Unions whose members will be exposed to programmable automation include those representing workers in metalworking manufacturing industries, such as the United Auto Workers, the International Association of Machinists (IAM), the International Brotherhood of Electrical Workers, and others that are listed in a paper by W. Cooke, appendix C. Although the median size for national unions is around 25,000 members, several unions representing manufacturing workers are among the largest, with memberships between 100,000 and 1.5 million.[3] See table B-1. While unions may influence the adoption of programmable automation and its impacts on their members, the adoption of programmable automation may in turn affect the strengths and abilities of unions insofar as job content, numbers of different types of workers, wage levels, and job satisfaction levels change. How unions change as programmable automation is adopted has implications for both the spread of automation and the characteristics of industrial relations.

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[1] Peter Feuille and Hoyt N. Wheeler, "Will the Real Industrial Conflict Please Stand Up?" in *U.S. Industrial Relations 1950-1980: A Critical Assessment*, Jack Steiber, et al. (eds.) (Madison, Wis.: Industrial Relations Research Association 1981).

[2] Ibid.

In addition to unions, and to the various entities that influence labor-management relations in unionized settings (e.g., the National Labor Relations Board, the Federal Mediation and Conciliation Service, arbitrators, and the courts), there are other institutions that shape industrial relations in both unionized and nonunionized settings and that may influence the adoption of programmable automation and its impacts. These include labor-management committees (instituted in both unionized and nonunionized settings), and government regulatory agencies such as the Occupational Safety and Health Administration and the Equal Employment Opportunity Commission.

The remainder of this section will provide a brief description of the collective bargaining process and outline some of the issues facing labor organizations and management in the context of the spread of programmable automation. Union and management attitudes and practices regarding education and training and working environment issues are addressed elsewhere in this report. Industrial relations in nonunion settings is not addressed in this technical memorandum.

Legal/Regulatory Framework

The central feature of labor-management relations in the unionized setting is collective bargaining, the process of negotiating the terms and conditions of work that will be codified in a contract that may apply for a period of 1 to 3 or more years. Guidelines for collective bargaining governing the processes of unionization and selection of worker representatives, procedures for bargaining and resolving disputes, and

Table B-1.—National Unions and Employee Associations Reporting 100,000 Members or More, 1978[a]

Organization[b]	Members (in thousands)
Unions:	
Teamsters (Ind.)	1,924
Automobile Workers (Ind.)	1,499
Steelworkers	1,286
State, County	1,020
Electrical (IBEW)	1,012
Machinists	921
Carpenters	769
Retail Clerks	736
Service Employees	625
Laborers	610
Communications Workers	508
Clothing and Textile Workers	501
Meat Cutters	500
Teachers	500
Operating Engineers	412
Hotel	404
Ladies' Garment	348
Plumbers	337
Musicians	330
Mine Workers (Ind.)	308
Paperworkers	284
Government (AFGE)	266
Electrical (IUE)	255
Postal Workers	246
Letter Carriers	227
Unions:—Continued	
Government (NAGE) (Ind.)	200
Railway Clerks	200
Rubber	200
Retail, Wholesale	198
Painters	190
Oil, Chemical	180
Fire Fighters	176
Transportation Union	176
Iron Workers	175
Bakery, Confectionery, Tobacco	167
Electrical (UE) (Ind.)	166
Sheet Metal	159
Transit Union	154
Boilermakers	146
Transport Workers	130
Printing and Graphic	120
Maintenance of Way	119
Woodworkers	118
Office	105
Associations:	
National Education Association	1,696
Nurses Association	187
Classified School Employees	150
Police	140
California	105

[a] Based on reports to the Bureau. All unions not identified as (Ind.) are affiliated with the AFL-CIO.
[b] For mergers and changes since 1978, see app. A.

SOURCE: U.S. Department of Labor, "Directory of National Unions and Employee Associations, 1979."

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[3] U.S. Bureau of Labor Statistics, *Directory of National Unions and Employee Associations*, 1980.

the sanctioning of unfair labor practices on the part of both management and labor, are found in several pieces of Federal legislation: 1) the National Labor Relations Act (Wagner Act/NLRA) of 1935, which established the National Labor Relations Board (NLRB) for labor practices rulemaking, investigation, and dispute-adjudication; and 2) its amendments promulgated in 1947 (Taft-Hartley Act) and 1959 (Landrum-Griffin Act).[4] The statutory framework for collective bargaining has remained unchanged since 1959, although attempts at legal reform were made unsuccessfully in the late 1970's.

Labor contracts can have enormous influence on how programmable automation affects existing and future workers in unionized firms. What kind of influence they have depends on what is included in the contracts, how the contracts are administered, and how NLRB, arbitrators, and courts interpret provisions subject to dispute.

The NLRA established that "wages, hours, and other terms and conditions of employment" constitute mandatory bargaining material. NLRB has interpreted this provision to mean that labor and management may negotiate over issues in two categories, one category of issues for which bargaining is mandatory, and one category of issues for which bargaining is permissible but not mandatory. NLRB and court rulings on the adoption of (conventional) automation through the 1970's generally imposed a requirement to bargain as to the effects of automation on workers, but not on the decision of whether and when to introduce automation.

Automation and the Law

Past NLRB and court rulings have generally treated the decision to automate as protected by "managerial rights" established in labor contracts. The breadth of the managerial rights protection depends on the language of the contract and its interpretation, given management's other obligations. Managerial rights have been construed to apply (in the absence of proven anti-union conduct) to the control of the production process, including the making of changes in property, plant, and equipment associated with production. Although changes in property, plant, and equipment can affect the terms and conditions of employment, and can, especially in the long term, lead to reductions in company employment levels, NLRB rulings to date imply that employers need not bargain where new technology "does not deprive employees of jobs, work opportunities, or otherwise cause a real change in working conditions" immediately.[5] Similarly, arbitration rulings regarding the interpretation of existing contracts suggest that management is accorded broad discretion for implementing new technology, altering work rules, and reallocating work between employees in the bargaining unit and others as a result of technological change, in the absence of specific contract language governing such changes.[6]

Both the language of NLRA and past rulings of NLRB and the courts leave unanswered many questions regarding the scope and timing of bargaining to which an employer is obligated regarding the adoption of new technology in general and programmable automation in particular.[7] Consequently, in the absence of new legislation, the development of clearer standards for collective bargaining regarding programmable automation would appear to await the passage of time and the development of precedents through NLRB and court rulings. The development of precedent, in turn, will depend in part on the changing membership of the NLRB which is comprised of presidential appointees serving 5-year terms.[8] Additional discussion of the role of NLRB may be found in a paper by W. Cooke, appendix C.

Contract Language

Existing contracts vary greatly in the degree to which they can influence the adoption of programmable automation or its effects. The substantive focus of most labor contracts has historically been on such matters as wages and hours, work rules and labor grades, and procedures for grievance resolution. Indeed, a government survey of labor contracts covering at least 1,000 workers that were in effect at the beginning of 1980 indicates concern over only one issue directly relevant to the adoption of programmable automation —advance notice of technological change. See table B-2. The general lack of specificity of past contracts with respect to technological change suggests that most unionized workers are preoccupied with the so-called "bread and butter" issues of wages and hours and that they may accept management's responsibility to make and implement decisions necessary to keep the company financially healthy and competitive—except, perhaps, where those decisions can be clearly linked to threats to job security. The infrequency of specific language regarding technological change may also reflect a lack of appreciation on the part of workers of how technological change may affect employment

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[4] 29 U.S.C. sec. 151-167 (1964).

[5] Joseph Manners, "New Technology and the Law," notes for remarks presented at IAM Electronics and New Technology Conference, Sept. 21, 1982.

[6] Doris B. McLaughlin, "The Impact of Labor Unions on the Rate and Direction of Technological Innovation," report prepared for the National Science Foundation (Detroit, Mich.: Wayne State University, Institute of Labor and Industrial Relations, 1979); and Manners, op. cit.

[7] "Notes: Automation and Collective Bargaining," *Harvard Law Review,* 84, 1971.

[8] Robert S. Greenberger, "Reagan NLRB Tilts Toward Management," *Wall Street Journal,* Aug. 2, 1982.

Table B-2.—Major Collective Bargaining Agreements Advance Notice Provisions by Industry
(agreements covering 1,000 workers or more, January 1, 1980)

Industry	All agreements		Requiring advance notice							
			Total		Layoff		Plant shutdown or relocation		Technological change	
	Agreements	Workers	Agreements	Workers	Agreements	Workers	Agreements	Workers	Agreements	Workers
All industries	***1,550***	***6,593,800***	***796***	***3,689,100***	***682***	***2,986,700***	***150***	***709,200***	***162***	***1,201,650***
Manufacturing	750	3,025,150	499	2,202,350	431	1,756,750	108	504,950	81	713,950
Food, kindred products	79	234,200	45	159,900	36	80,000	14	89,900	12	32,650
Tobacco manufacturing	8	21,800	8	21,800	5	16,100	6	11,800	—	—
Textile mill products	11	28,850	7	21,000	2	2,300	1	5,000	6	19,800
Apparel	31	207,900	11	118,000	2	6,200	2	18,200	8	96,800
Lumber, wood products	11	17,100	4	6,700	4	6,700	1	1,500	—	—
Furniture, fixtures	17	23,100	11	13,100	9	10,800	2	2,300	—	—
Paper, allied products	42	65,000	20	34,900	10	17,950	9	15,250	9	17,100
Printing and publishing	15	31,600	14	30,600	12	28,400	3	3,300	9	24,800
Chemicals	36	61,700	25	38,850	23	34,450	2	3,600	5	9,000
Petroleum refining	15	25,500	9	15,500	8	13,000	6	11,600	1	1,700
Rubber and plastics	14	68,850	12	52,500	9	20,250	4	34,050	2	23,450
Leather products	11	23,100	5	9,750	3	6,300	1	1,100	2	3,450
Stone, clay, and glass	35	93,600	28	83,050	21	67,750	15	51,150	7	17,350
Primary metals	88	460,600	48	193,600	43	126,550	7	75,650	3	8,800
Fabricated metals	41	97,000	35	87,150	32	79,750	6	11,600	—	—
Nonelectrical machinery	81	242,150	65	212,100	64	210,900	11	50,150	7	12,650
Electrical machinery	83	323,750	61	259,850	59	188,300	10	99,700	1	9,000
Transportation equipment	112	957,100	76	810,150	74	807,200	5	13,550	9	437,400
Instruments	11	27,650	11	27,650	11	27,650	3	5,550	—	—
Miscellaneous manufacturing	9	14,600	4	6,200	4	6,200	—	—	—	—
Nonmanufacturing	800	3,568,650	297	1,486,750	251	1,229,950	42	204,250	81	487,700
Mining, crude petroleum, and natural gas	16	169,050	6	148,200	4	133,200	—	—	3	140,000
Transportation[a]	62	469,550	24	128,600	16	56,950	10	78,950	5	23,650
Communications	80	620,000	63	492,450	61	483,650	3	18,250	7	67,450
Utilities, electric, and gas	81	210,700	53	155,800	50	135,350	2	3,750	9	36,450
Wholesale trade	12	23,900	8	18,250	5	11,200	1	1,550	2	5,500
Retail trade	123	405,200	82	304,450	64	226,500	17	48,000	43	146,950
Hotels and restaurants	31	148,300	12	51,050	10	32,250	1	1,000	3	21,750
Services	66	323,450	28	115,600	22	96,150	5	31,500	9	45,950
Construction	327	1,195,000	21	72,350	19	54,700	3	21,250	—	—
Miscellaneous nonmanufacturing	2	3,500	—	—	—	—	—	—	—	—

NOTE: Nonadditive.

[a] Excludes railroads and airlines.

SOURCE: U.S. Department of Labor, "Characteristics of Major Collective Bargaining Agreements, January 1, 1980," May 1981.

and working conditions, and/or an inability of unions to negotiate successfully for such language.

Overall, the scope of labor contracts began to expand beyond traditional provisions in the 1960's in response to technological change, growth in foreign competition, and growth in the practice of subcontracting work to both domestic, and particularly foreign, firms. Clauses in the following areas, which may be relevant to the adoption of programmable automation, have become more common during the past two decades:

- *Job and Wage Security.* Retraining (for whom, who pays); layoff, transfer, and relocation procedures; "red-circling" (maintenance) of wages of persons transferred to lower paying jobs; severance payments; early retirement.
- *Technology Change.* Advance notice; consultation; establishment of labor-management advisory committees.

In 1966 the Automation Commission endorsed the practice of advance notice of technological change as a measure that the private sector could take to facilitate adjustments in the labor market, together with explicit advance planning by companies for attrition and other internal work force adjustments.[9] A comparison of contract scope in the mid-1960's and the early 1980's is provided in a paper by M. Roberts, appendix C.

Additional areas for labor contract change in connection with programmable automation include modification of work hours (currently included in some contracts as a means of adapting to periods of slack business), specific triggers for reopening negotiations before contracts formally expire, procedures for reclassifying workers, definition of and assignment of work to the bargaining unit, and involvement of labor representatives in planning, design, and purchase decisions for automated systems. Whether, when, and how labor contracts accommodate the adoption of automation will depend on many factors, such as the duration of the current concessionary bargaining trend and the weight given to technological change relative to other concerns by both labor and management. IAM, for example, appears to attach great weight to technological change, especially automation, as a bargaining issue; it has included technological change provisions in model contract language it has developed since the 1960's. In 1982, two IAM locals engaged in long-term strikes over proposed work-rule changes associated with programmable automation.[10]

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[9] *Technology and the American Economy,* report of the U.S. National Commission on Technology, Automation, and Economic Progress, February 1980.

A key question with regard to the impacts of programmable automation on industrial relations among unionized firms is whether the collective bargaining framework is adequate for meeting needs of both labor and management with respect to programmable automation. At this time, there does not appear to be empirical data suitable for evaluating how programmable automation may affect industrial relations, and vice versa. Participants in the OTA Labor Markets and Industrial Relations Workshop appeared to agree that collective bargaining can accommodate new needs associated with programmable automation, although some participants maintained that the resiliency of collective bargaining depends in part on how the relative bargaining power of unions and management changes in response to new technology and to other factors. A discussion of relative bargaining power is provided in a paper by W. Cooke, appendix C.

Institutional Change

The overall bargaining power of unions relative to management and the overall role played by unions in the transition to new manufacturing technologies, including programmable automation, depend on the extent of union representation and on the response of unions to specific aspects of programmable automation (and other new technologies). Factors influencing union representation and union responses to new technology are outlined below.

Union representation is largely a function of numerical strength. Changes in the numerical strength of the labor movement as a whole are widely acknowledged. Although membership in labor organizations has grown, the proportion of the labor force that is organized and the rate of growth of union membership have both declined during recent decades, and unions have been less successful in arranging and winning elections. Moreover, unions have become less successful in overcoming decertification efforts in the past few years. See figure B-1.

Factors Influencing Union Representation

The erosion of overall union representation has been attributed to many factors, including changes in em-

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[10] Marilyn Chase, "Work Rule Changes Sought," *American Metal Market/Metalworking News*, Oct. 25, 1982.

Figure B-1.—Change in Union Representation Over Time

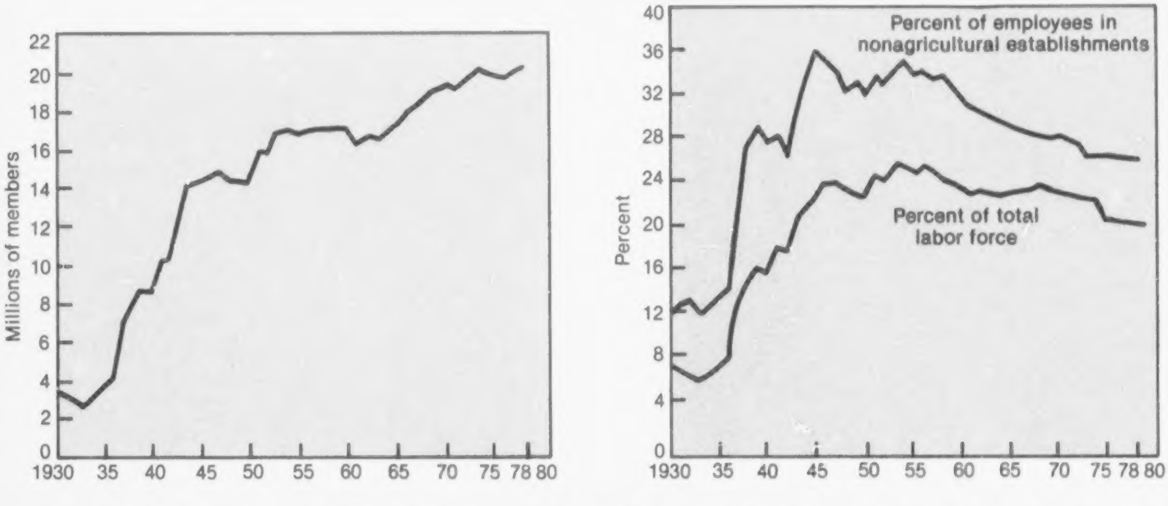

Chart 1. Membership of national unions, 1930-78[a]

Chart 3. Union membership as a percent of total labor force and of employees in nonagricultural establishments, 1930-78[a]

[a] Excludes Canadian membership but includes members in other areas outside the United States. Members of AFL-CIO directly affiliated local unions are also included. Members of single-firm and local unaffiliated unions are excluded. For the years 1948-52, midpoints of membership estimates which were expressed as ranges were used.

SOURCE: U.S. Department of Labor, "Directory of National Unions and Employee Associations, 1979."

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ployer practices (as a factor enhancing employer effectiveness in avoiding unionization), relocation of production, structural change in the economy, and proliferation of new parties to industrial relations activities. It is uncertain, however, whether the overall economic strength of unions has declined commensurately.

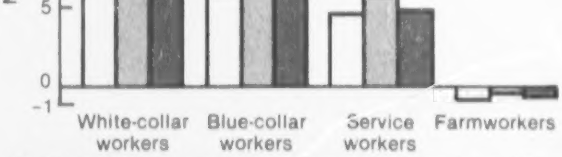
Modern personnel practices may diminish the incentive of workers to organize where management provides grievance procedures, complaint channels, company information, fair compensation, and other services or benefits that unions have been instrumental in launching at unionized firms. Personnel practices have improved as a result of growth in government regulation of employment conditions, growth in business school training of managers, increased attention of business school curricula to human resource management, and other factors.[11] One industrial relations analyst relates change in employer practices to the spread among managers of the view that "unions exist as a reflection of management failures," although he notes that such generalizations tend to be unmerited, reflecting doctrine rather than analysis of specific situations.[12] A review of the industrial relations literature shows that this characterization appears to be accepted by many academic observers of industrial relations trends.

The shift in location of production from unionized to nonunionized regions in the United States, and from the United States to other countries, has also diminished the union presence in the workplace. Locational shifts occur for many reasons, most related to costs, and in some cases including a desire by management to evade unions.[13] Where locational shifts involve plant closings, unions can gain political support through community opposition to closings.* On the other hand, management develops political support (though not necessarily at the local level) by relating locational and other decisions to business strategy for maintaining competitiveness. Although "competitiveness" has become a battle cry in rhetorical wars between unions and employers, the true extent of the effect of unions on industrial competitiveness, and the soundness of that rationale for relocating production facilities away from unionized areas, are uncertain.

Another important factor in observed erosion of union representation is structural change in the economy. In brief, growth in service industry relative to manufacturing employment, and growth of public sector relative to private sector employment have increased the proportion of employment opportunities in occupations and industries with traditionally limited union representation. See figure B-2. Moreover, growth in electronics and other so-called "high tech" industries which have little union representation relative to traditional manufacturing has also reduced the proportion of employment in unionized industries (although unionized, traditional manufacturing industries employ more people than high-tech industries).* The continuation of these divisions between predominantly union and nonunion industries and sectors is uncertain.

Finally, several new parties have entered the industrial relations arena in the past two to three decades. First, the use of consultants who specialize in personnel management and in combating unions and the establishment of labor-management committees have grown among both unionized and nonunionized firms.** Although the legality of labor-management committees in unionized firms has been questioned (as possibly unfair employer interference in the bargaining process), and although some unions regard committees as conflicting with the bargaining process, many committees have been established through collective bargaining, and legal problems are being resolved.*** The long-term impacts of labor-manage-

Figure B-2.—Job Growth for Major Occupational Categories Under Alternative Economic Projections, 1978-90



SOURCE: Bureau of Labor Statistics, "Monthly Labor Review," August 1981.

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[11] D. Quinn Mills, "Management Performance," and Fred K. Foulkes, "Large Non Unionized Employers," in *U.S. Industrial Relations 1950-1980: A Critical Assessment*, Jack Steiber, et al. (eds.) (Madison, Wis.: Industrial Relations Research Association, 1981).

[12] Ibid.

[13] Ibid.

*Point debated in 1982 OTA Labor Markets and Industrial Relations Workshop.

*A BLS analysis conducted for the Joint Economic Committee notes that high-tech industries account for 4.6 percent of total wage and salary employment. By contrast, all manufacturing industry wage and salary jobs comprise about 22 percent of the total.

**This point was raised at the OTA Labor Market and Industrial Relations Workshop and in a roundtable reported in *Fortune* magazine, Sept. 20, 1982.

***Point discussed at the OTA Labor Market and Industrial Relations Workshop.

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ment committees on union-management relations are unclear, since existing committees differ in focus (e.g., training, quality control) and scope, and since the current increase in interest in committees seems linked at least in part to current economic conditions and import levels.

Second, new regulations and regulatory bodies began to influence labor-management relations in the areas of occupational safety and health protection and equal opportunity in hiring and promotion in the 1960's and 1970's, beginning with the 1969 Coal Mine Health and Safety Act and continuing with the 1970 Occupational Health and Safety Act and the 1972 Equal Employment Opportunity Act.[14] New regulations served to force changes in union practices, including contract modification. Some observers believe that government regulation of hiring, promotion, and occupational health and safety practices may have undermined the value of collective bargaining in those areas, by establishing new complaint mechanisms for workers outside the traditional industrial relations framework, and placing an emphasis on concerns of the individual worker rather than the bargaining unit.[15] Occupational health and safety regulations, in particular, may also affect unions by promoting technology change in general and automation in particular. And, as noted earlier, regulations motivated improvement in personnel management.

Programmable automation may present opportunities or liabilities for labor organizations. How labor organizations are affected by programmable automation depends on how the equipment and systems are developed and implemented, and on where they are used. To develop an understanding of how programmable automation may affect labor organizations, a variety of issues should be addressed, such as the aspects of programmable automation design and implementation that may be fundamental to union (and other labor) responses to programmable automation, the degree to which workers consider programmable automation design and implementation characteristics to be inevitable or negotiable, and, in particular, the impact of programmable automation on the organizing base for unions.

While unions are perceived as representing primarily production workers, the application of programmable automation to all aspects of the manufacturing process, including nonproduction activities such as drafting and inventory control, may broaden the base of workers interested in organizing. Already, scientific/engineering and clerical unions have been formed, serving constituencies which may be especially vulnerable to technological change in the future. Whether nonproduction workers do organize at higher rates, and if they do, whether they join unions dominated by production workers or separate labor organizations, may be important factors in determining how labor organizations influence the spread of programmable automation and moderate its impacts.

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[14] Public Law 91-173, Public Law 91-596, and Public Law 92-261, respectively.

[15] Phyllis A. Wallis and James W. Driscoll, "Social Issues in Collective Bargaining," in *U.S. Industrial Relations 1950-1980: A Critical Assessment*, Jack Steiber, et al. (eds.) (Madison, Wis.: Industrial Relations Research Association, 1981).

Appendix C

Papers Prepared for Workshop

The following papers were prepared as background materials for the OTA Labor Markets and Industrial Relations Workshop which was held July 27, 1982. *Their content and conclusions are the sole responsibility of the authors and do not necessarily reflect the views of OTA.*

1. "The Economics of Technical Progress: Labor Issues Arising From the Spread of Programmable Automation Technologies," by Eileen Appelbaum.
2. "Assessing the Future Impacts on Employment of Technological Change: An Input-Output Approach," by Faye Duchin.
3. "The Effect of Technical Change on Labor," by Louis Jacobson and Robert Levy.
4. "Programmable Automation: Its Effect on the Scientific-Engineering Labor Market," by William N. Cooke.
5. "Technology and Labor," by Markley Roberts.
6. "Labor-Management Relations in an Era of Programmable Automation," by William N. Cooke.

THE ECONOMICS OF TECHNICAL PROGRESS: LABOR ISSUES ARISING FROM THE SPREAD OF PROGRAMMABLE AUTOMATION TECHNOLOGIES

by Eileen Appelbaum*
Department of Economics
Temple University

July 27, 1982

One of the specific objectives of this workshop is to place alternative analytic methods which may be used to make inferences about programmable automation technologies and labor market issues in perspective. A second objective is to specify the information requirements associated with the formulation of appropriate policies and legislative initiatives. The two objectives are related in that the choice of variables for study as well as the specification of the behavioral relations among them is dictated by the system of analysis that is utilized. My remarks are directed to the second set of questions which this panel will be considering, subsumed under the heading, "To what extent are the production and use of programmable automation likely to result in unemployment of current workers and job displacement?" My view is that an adequate system of analysis is indispensable to an evaluation of the questions raised in this section and to the design of studies capable of providing reliable information.

The first section of this paper is a critique of the standard economic analysis of technology and employment. This view probably exercises some influence in the policy community and elsewhere. Its conclusions are remarkably sanguine. They may or may not prove to be true; but the analysis itself is faulty and the conclusions are not supported by it. I will keep my comments brief, and will limit them to demonstrating the most critical weaknesses of this approach. In the next and most important section I will proceed to the constructive task of developing the economics of technical progress to encompass the issues of interest to this panel. The analysis presented in this section will, I believe, make clear the existence of important relationships that are not otherwise obvious, and will provide qualitatively new insights in the analysis of the employment issues. The final section will indicate the kinds of studies that will best serve to increase our knowledge of the effects of this latest round of automation on workers, jobs, and employment.

Critique of the Standard Economic Analysis of Technology

The analytical methodology employed by economists to analyze the effects of the introduction of robots on wages and employment of workers in the affected industries and upon employment generally tends to trivialize what is a complex question, and offers little policy guidance. This does not *appear to* create any difficulties, mainly because the analysis leads economists to the conclusion that, apart from a short-term need for retraining, workers face no problems. Thus, standard analysis suggests that robotics: 1) will have a positive impact on wage levels, 2) will probably tend to reduce rather than increase unemployment in the long run, and 3) will stimulate total employment even in the industry introducing the robots.[1] The analysis on which these conclusions are based can only be characterized as glib and superficial.

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*The author is a member of the Working Group on Reindustrialization at the University of Massachusetts (Amherst) and participates in its Subgroup on Microelectronics and Work Process. She is indebted to her colleagues for valuable discussions, though she is solely responsible for the content of this paper and any errors in it.

In analyzing the wage and employment effects of introducing robots, a typical approach taken by economists is to present a hypothetical situation. One typical presentation compares the case in which a widget factory adds one additional worker to its existing production line and increases output by 4 units a day to the case in which the firm buys several robots and hires one additional worker to oversee them, thus increasing output by 10 units a day. At $20 per widget, the author concludes that the value of a worker's marginal product has increased from $80 to $200 and that the firm, which previously would have been unable to pay any worker more than $80 will now be forced by competition to pay this new worker something near the $200 figure. This type of example, though common, is peculiar; and the argument behind it is logically incorrect.

It is strange that in this example the robots do not replace any previously employed workers (welders, painters, machinists, etc.), but are simply added to an existing production process. It's an unusual technology, indeed, that simply adds two or three robots to an existing process without materially affecting that process. As no workers have been replaced, utilization of the robots simply *increases* employment by one skilled worker because the robot requires maintenance and oversight. Economists making this argument sometimes conclude that the worker hired will be a skilled worker. Now, robot-fixer may be a more skilled job than painter or welder, but robot-minder is not. With only two or three robots, the firm is likely to contract out for robot maintenance, increasing employment in the contracting firm by considerably less than one skilled worker. The worker hired by the firm using only two or three robots is more likely to be a relatively unskilled adjunct to the robot. By making the robot overseer both robot-minder and robot-fixer, this approach manages to evade entirely the issues involved in the fact that some skills will be downgraded even as others are increased.

Moreover, the argument is logically incorrect. In going from the first case to the second, an increase of capital (two or three robots) as well as an increase of labor (one robot-fixer) has been slipped into the example. Capital and labor have *both* increased, and consequently it is not possible to speak of an increase in the marginal product of labor. Nor can the firm afford to use the total increase in productivity to increase wages. What this argument appears to ignore is that with an increase in wages for the newly hired worker from $80 to $200, the rate of profit on capital has decreased. The *amount* of capital has increased by two or three robots, but all the increase in output has gone to pay the wages of the robot-fixer. Consequently, gross profits are unchanged. As a result, the ratio of net profits to capital (the rate of profit on capital) has decreased. An even more serious consequence is that, with gross profits unchanged, the firm will be unable to amortize the new robots. How will it replace them as they wear out?

Economists sometimes use oligopolistic industries like auto and steel as illustrative examples in considering what will happen to the price of, and demand for, output. In these examples, price and quantity sold of steel and cars are determined by impersonal market forces. Auto and steel firms exercise no control over market price and, in particular, they do not view price as a strategic variable which they can manipulate to restore profitability after the introduction of robots. Nor are steel or auto workers capable of bargaining for higher money wages as their productivity increases. Thus, the introduction of robots reduces production costs, increases supply, and ultimately causes prices to decline and the quantity demanded to increase. The problems with this analysis when applied to industries like steel and autos are myriad. If firms exercise market power to increase profit, or workers bargain for wage increases, or the new technology requires greater investment, or the new technology is likely to become obsolete in a short time as robots become more sophisticated and hence has higher amortization costs, then the decline in production costs will be damped, supply need not shift very much, prices need not fall very much, and the quantity demanded need not be much affected. Real wages and/or profits will increase and demand may very well be affected, but simple textbook models of supply and demand are not sufficient for analyzing industries that are highly unionized, capital intensive, and in which firms are able to exercise market power. An alternative analysis which poses very different questions and possibilities, is a prerequisite to research.

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[1] See, for example, Richard K. Vedder, "Robotics and the Economy," a staff study prepared for the Joint Economic Committee, Congress of the United States, Mar. 26, 1982 (Washington, D.C.: U.S. Government Printing Office, 1982).

On one point standard economic analysis is correct: there is no stopping the introduction of robots. Even if it should turn out that employment is adversely affected and the rate of profit on capital is approximately the same after the introduction of robots as it was before, firms cannot avoid trouble by never adopting the new technology. So long as some firms (in this case, Japanese or European firms) are going to introduce the new technique, U.S. firms will have to do likewise or find they are unable to compete in world markets. In the absence of competition, firms have sometimes delayed the introduction of cost saving techniques to protect the value of existing capital. In the presence of competition, delay risks loss of sales and, hence, of jobs. U.S. firms will ultimately have to adopt robotics and related tehnologies. If they do so later rather than sooner, they will lose whatever advantages accrue to having been among the leaders.

The Economics of Technical Progress: Labor Issues Arising From the Spread of Programmable Automation Technologies[2]

Programmable automation technologies are introduced in order to reduce manufacturing cost per unit of revenue. That is, as a result of robotics, firms expect their net receipts from a given outlay to be higher than they would have been otherwise. A successful innovation reduces costs—saving labor cost, or saving capital cost, or expanding the resource base and thus saving resource cost. An innovation may be worth making even if it raises one element of cost provided that it reduces other elements more. Thus, programmable automation technologies will be introduced because they reduce labor costs by increasing output per man-hour or by allowing the substitution of cheaper for higher paid labor, or because they reduce amortization charges by embodying major advances in technique in new plant and equipment, thus reducing the risk that the capital stock will become prematurely obsolete and extending its probable useful life. Such changes in technique may be cost saving even if they increase capital costs. The effect of the new technologies on wages and employment will vary, however, depending on whether they are capital saving or capital using. Capital costs are increased, and the new technique may be characterized as *capital using,* if the firm requires higher levels of investment in order to achieve a given increase in capacity. It may be characterized as *capital saving* if less investment will achieve a given increase in capacity, and it may be characterized as neutral if the amount of investment required to achieve a given increase in capacity is the same with the old and new techniques.

Whether they are capital using or capital saving, programmable automation technologies are labor saving. A saving in labor cost may be due to an increase in output per man-hour with the type of labor (i.e., the distribution of skill levels) unchanged, or it may be due to the substitution of less skilled labor for more skilled. It will, thus, be necessary to consider several cases.

Wage and Employment Effects

Programmable automation technologies are likely to spread throughout the manufacturing sector, though they may have fewer applications in some industries than in others. Consider first what will happen if these technologies are capital saving (or neutral) and, in addition, are labor saving due to an increase in output per man-hour and not due to the deskilling of work. If money wage rates are unchanged following the introduction of robots and related technologies, then the effect of these innovations depends on what happens to the price of manufactured goods. If the price of these products is unchanged, the net profit per unit of output and net profit per unit of capital will be increased. Real wages will be unchanged. If the prices of these products decline, as a result perhaps of the strength of foreign competition for the domestic market, then real wage rates will rise. The increase in real wages will be greatest when competition is strong enough to force prices down to the point at which net profit per unit of capital is the same after the change in technology as it was before the change. Lesser price decreases imply an increase in the rate of profit and smaller increases in real wages. An alternative scenario is one in which money wage rates increase in line with productivity advances so that unit labor costs are constant while prices are constant or increase. Again, so long as competition is sufficient to assure that prices increase by less than wages, real wages will increase. The extent of the increase in real wages will depend on the strength of competition in product markets, which limits the increase in the rate of net profit on capital following the introduction of the new technique. Provided that competition in product markets is not entirely absent, *real wages of manufacturing workers will increase following the spread of programmable automation techniques if the proportion of skilled manufacturing jobs does not decline.*

The effect on employment in manufacturing depends, in the first instance, on what happens to effective demand for manufactured commodities and capital goods. To maintain a given level of manufacturing employment, demand for manufactured goods (including robots) must increase in the same proportion as output per worker. If the new technology is capital saving (or neutral), then the increase in capital goods required to maintain a given level of employment will be less than proportionate (just proportionate) to the increase in output forthcoming from that employment. Then *the increase in demand (including export demand) for manufactured commodities will have to increase more rapidly than (at the same rate as) output per head in order to maintain employment constant.* If effective demand for manufactured products does not grow apace, technological unemployment in manufacturing will result. Keynesian demand management policies may or may not be capable of increasing effective demand sufficiently to prevent unemployment in individual industries—it depends on the extent to which the new technology increases output per worker. Given worldwide excess capacity in steel production, for example, reliance on demand management alone is insufficient to restore the U.S. steel industry's employment to its 1979 level, even after cost saving robots are introduced.

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[2] This argument owes much to Joan Robinson, "Notes on the Economics of Technical Progress," *The Generalisation of the General Theory and Other Essays* (New York: St. Martin's Press, 1979 (1952)). The importance of capital saving technology in economic development was suggested to me by Professor Thomas Hughes of the University of Pennsylvania.

A reduction in the workweek with no reduction in weekly income is an alternative means of maintaining employment in manufacturing. The question that arises is whether this can be done without raising unit labor costs or reducing real weekly wages. If the new technology is capital saving or neutral and doesn't reduce the proportion of skilled jobs, the answer is "yes." *With output per worker increasing and the ratio of investment to output constant or declining, it is always feasible to reduce the workweek without a reduction in weekly income or an increase in price.* The increase in labor productivity in an industry may be shared between a slower increase in weekly income and a reduction in the workweek for workers in that industry.* A reduction in the workweek under these circumstances is always possible. There are at least two reasons, however, why it may not be practical. First, a shorter workweek is only possible if prices of the industry's products do not decline. In the face of international competition for domestic markets, it may not be possible to meet this condition. Second, consider what happens when some manufacturing industries are better able than others to utilize the new technologies, and thus achieve much greater increases in productivity. If the standard workweek in manufacturing is reduced, the reduction is likely to apply to all manufacturing industries, including those with slower productivity gains. Labor costs and prices in industries where productivity improves less must rise as a result of the reduction in the workweek. If the products of such industries are capital goods, they will raise the final price of the outputs of the technically progressive industries in which they are used, possibly making them less competitive in world markets. In any event, the increase in the price of output of industries where the new automation tehnologies are less applicable retards the rise in real wages of workers. *Thus, a reduction in the weekly hours of manufacturing workers with no reduction in weekly income can most easily be undertaken if: 1) programmable automation technologies prove to be capital saving or neutral, 2) real wages of workers rise because money wages increase in line with productivity increases while prices remain constant (and not because money wages remain constant while prices decline), and 3) the technologies are widely spread among manufacturing firms and not much more highly concentrated in some than in others.*

If programmable automation technologies are capital using rather than capital saving or neutral, the discussion of the effect on real wages has to be modified somewhat. Again, if money wages and prices are both unchanged, net profit per unit of output will increase. Whether any increase in the rate of profit on capital and/or real wages is possible depends on whether the increase in the amount of capital required per unit of output and in net profit per unit of output are proportionate. That is, it depends on whether the saving in labor cost is completely offset by the increase in capital costs. *If it is not entirely offset, then provided competition in product markets is not entirely absent, real wages of labor will rise.* The increase, however, will be more moderate than if the technology were capital saving or neutral. The reason for this is straightforward: If the new technologies are capital using, a larger share of gross output will be required for amortization. The increase in net output available to be divided between increases in real wages and in the rate of profit is consequently smaller. For the same reason, the possibilities for trading off increases in real wages for a shorter workweek are more limited.

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*The following example may clarify this point. Consider a firm that employs 10 workers at 40 hours a week and produces 100 widgets a week. The workers are paid $1.00 an hour and the widgets are priced at $5.00 each. Each worker earns $40 per week. The total wage bill is $400 and total profits are $100. Now suppose a capital saving advance in technology is introduced that increases output per worker by 50 percent, and that wages also rise by 50 percent to $1.50 an hour. Suppose that demand for widgets increases, but not enough to maintain employment of all 10 workers. Suppose that demand for widgets increases to 120 a week. Following the advance in technology, this output can be produced with only eight workers. The total wage bill is now $480 (eight workers working 40 hours at $1.50 an hour). The wage bill has increased 20 percent. With no increase in price, total profits will increase to $120, also a 20-percent increase. The eight workers are employed a total of 320 hours a week. If a decision is made to maintain employment by reducing the workweek, the 10 workers will each work a 32-hour week. At $1.50 an hour, each worker will earn $48 a week. The workweek has decreased, labor costs have not increased, real weekly wages have increased (though more slowly than they otherwise would have), and the increase in profits is unaffected.

Even when demand for manufactured goods grows in line with the growth of output per worker, a capital saving technology will not directly increase employment in the capital goods industries. A capital using technology, however, may have this effect. With investment requirements higher, whether employment will increase in the capital goods industries depends on whether these industries have also introduced labor saving technologies as they shifted from the production of ordinary to programmable automation technologies.

An important motive for the decision of firms to introduce capital using techniques is that such techniques may substitute machinery for skill, reducing the skill component of the task, and making possible the substitution of lesser skilled machine-tenders for more highly skilled craftsmen.* Such developments in technology save labor costs by allowing firms to substitute cheap labor for more expensive, and bring us to the third case which must be considered. This type of technical change is, perhaps, more invidious than a change which saves labor by increasing output per worker without reducing skill requirements. One reason is that even if aggregate demand policies could be devised to maintain reasonable full aggregate employment levels, skilled manufacturing workers would be displaced by less skilled workers. If the wages of skilled workers do not then decline substantially, the new technique will diffuse through the industry, effectively displacing the skilled workers. A substantial decline in wages of skilled workers might check the spread of the new technique, allowing both techniques to operate side by side. This outcome, however, would probably require a decline in the wages of skilled workers sufficient to nearly eliminate the wage differential between skilled and unskilled workers. Unlike changes in technology that save labor costs by increasing output per worker, *changes in technology that save labor costs by enabling firms to substitute cheap, unskilled labor for more highly skilled workers do not increase real wages.* Whether the rate of profit on capital increases or not, net profit as a share of output and amortization will both increase as a result of the introduction of a more capital using technique. Given the overabundance of workers available for less skilled jobs in the U.S. economy, and their lack of union organization and bargaining strength, it is unlikely that real wage rates of less skilled workers will increase. Union organization of these workers could change this, of course, by capturing for the less skilled employees some part of the cost saving associated with the elimination of more highly skilled jobs. Otherwise, average wage rate in manufacturing will be reduced and the rate of profit increased. In any event, high wage jobs will have been eliminated.

This raises a related issue. As we have just seen, firms in an industry can improve their cash flow position (net profit plus amortization) by adopting a technique that is capital using but saves labor cost by allowing the substitution of less skilled labor for more skilled. For this reason, they may choose such a technique in preference to an alternative available technology that saves labor cost by increasing output per worker without reducing skill levels since such techniques, in general, increase real wages. Such a choice, however, may have serious negative ramifications for further technological change 10 or 20 years in the future. These negative impacts may affect the competitive position of such firms vis-a-vis foreign competitors who have chosen not to reduce the proportion of skilled workers employed. A hypothetical example, which Peter Albin of CUNY suggests may not be so far from the truth, may serve to illustrate this point. Suppose that when a U.S. firm puts in a robotic installation, it replaces as many as six master machinists with one programmer plus three entry-level people whose function is to "load and unload," keeping things lined up for the robots. In Japan, on the other hand, let us suppose that master machinists are retrained and prepared for positions as machinist/programers. The machinist's job is transformed but not downgraded, and the machinist is ready for future changeovers. The initial cash flow advantage is gained by the American firms which have a less skilled and lower paid labor force. However, the man/machine configuration in U.S. firms is more permanent, less flexible. In the absence of skilled master machinists, the opportunities for learning by doing are severely curtailed. The Japanese in this example, because they retain their master machinists, need to build less into the machine, can design less immutable man/machine configurations, have enhanced opportunities for learning by doing, and have increased opportunities for continuous technological change. Longrun competitive advantage would rest with the Japanese. This example suggests that the substitution of less skilled workers for craft and highly skilled workers, as a means of holding down costs and increasing profits in the near future, may be myopic. In the longer period, it could have serious implications for international competitiveness and manufacturing employment.

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*Such a development has occurred in the last decade in the baked goods industry. Bakers continued to be classified among craft workers although, increasingly, the baker's task has become one of minding, measuring, and mixing machines. Cheap labor, often female, has been substituted for highly skilled craft labor as mechanization increased and the job was deskilled.

Changes in Aggregate Employment Outside Manufacturing

Changes in technology that involve the deskilling of tasks have a deleterious effect on the employment possibilities of skilled manufacturing workers, while those that increase output per worker raise the specter of technological unemployment. Such unemployment will materialize if growth in demand lags behind productivity growth. In an open economy, in which imports supply some part of the domestic market, growth in demand at home and abroad for domestically produced manufactured products will have to outstrip the productivity gains just to maintain employment constant. Otherwise, as seems likely, employment in U.S. manufacturing will decline. The question, then, is whether employment in nonmanufacturing sectors of the economy will expand and absorb displaced workers as well as new labor force entrants who would previously have found skilled and semiskilled manufacturing jobs.

Economists are used to thinking of increases in productivity as increasing real income and spending, thus increasing demand for services and other products, as well as employment in the industries producing them. It happens, however, that it matters whether the increase in real income is an increase in real wage rates or an increase in net profit. An increase in net profit results in an increase in business saving, and sets up the conditions for a cyclical decline in employment. Moreover, the marginal propensity to save and to consume imports is higher among those income groups receiving dividends than among wage earners, again with negative implications for U.S. employment. Some part of the increase in net profits will increase demand for producer services (e.g., advertising, financial, architectural, or computer services), so that output of this sector will increase.

An increase in real wages, on the other hand, is likely to generate an increase in demand for the full range of consumer goods and services. Output will increase, but the effect on aggregate employment is more uncertain. Two cases need to be considered: the case in which technology in nonmanufacturing firms is essentially unchanged, and that in which labor saving programmable automation technologies spread through the nonmanufacturing sectors as well.

Suppose that the application of programmable automation technologies is confined to the manufacturing sector and does not spread to the two other broad sectors of the economy—other goods producing industries (agriculture, construction, and mining) and nongoods producing industries broadly construed as the service sector. Price declines for some manufactured goods, as a result of the increase in output per worker, are likely—in clocks, calculators, home computers, etc. Typically, however, real wages of manufacturing workers and profits of manufacturing firms will increase as a result of increases in money wages in line with productivity and prices that remain largely unchanged, perhaps creeping upward slightly.[*] With prices largely unchanged, real wages of nonmanufacturing workers are also unchanged. As manufacturing workers spend their higher real incomes, demand for nonmanufactured goods will increase. The higher incomes (gross profits and total wage bill, though not wage rates) generated in these sectors again increase demand for manufactured goods, other goods, and services. *Since existing technologies in the service sector have a much higher ratio of labor to "output," growth in services and consequently in service sector employment could possibly maintain aggregate employment, increasing the share of service jobs.*

The employment outcome is far less optimistic if unionized workers in construction, mining, transportation, and the public sector, concerned over the decline in their relative real wage position, bargain for higher money wages. The resulting rise in prices, especially of housing, will slow the increase in real wage rates due to the advance in technology in manufacturing, and hence will retard the increase in employment generated by expenditures out of increased wage income. Moreover, with prices rising the already low real wages of nonunionized workers in retail trade and health services, and of many of the clerical workers found in the service sector, will decline. The resulting change in relative output prices may stimulate demand for these services, resulting in a disproportionate increase in such low paying jobs.

It is not realistic, of course, to assume that programmable automation technologies will be limited to the manufacturing sector. In particular, the spread of distributed data processing in offices has already begun and should be well under way by 1990. Automation in manufacturing had progressed far even before the introduction of robots and related technologies. Reliable estimates of productivity growth as a result of these new techniques are not available, though the guess that is bandied around is that between 4 and 9 percent of the work in manufacturing is suited to such automation.[**] The effect on employment will be less than 4 to 9 percent since robot support staff—maintenance and repair personnel, programers, and machine-tenders—will be required. Productivity might increase by as much as 6 percent. These are only guesses, of course, but that future productivity gains in manufacturing will approximate current gains in a technologically progressive sector like communications, does not seem entirely unreasonable. Unlike manufacturing, automation in offices is a qualitatively new experience. Mechanization, in which machines supplement the input of workers, has occurred steadily with the introduction of typewriters, electric typewriters, and word processors as well as other business machines. But office automation, in which machines take over entire worker functions and drastically alter job content for the remaining workers is a recent phenomenon. Gradual gains in clerical productivity since 1948 may, within the decade, be replaced by rapid advances in output per worker. Again no reliable estimates of the potential spread of office automation have been made for the United States. European observers[3] suggest that 30 to 40 percent of clerical work may be suitable for automation, with the impact on employment in the 20- to 30-percent range. These guesses (and I emphasize that they are only guesses) suggest an increase in labor productivity in the office of about 25 percent. Even if these guesses are too high by a factor of 2 or 3, they suggest the severity of the technological unemployment problem that may emerge if programmable automation technologies spread through both manufacturing and nonmanufacturing sectors. With so small a fraction of clerical workers unionized and so large a percentage of them women, clerical workers are likely to reap but few of the gains of their higher productivity directly. Major employers of clerical workers—insurance companies, accounting firms, advertising agencies, computer service firms, law firms—may lower their rates, raising real incomes generally and stimulating demand for their services. Alternatively, net profits will increase if rates are unchanged. In either case, *the rapid growth that has characterized clerical employment in the last decade is likely to slow, further compounding the problem of providing jobs for new labor force entrants.*

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[*] Such was approximately the case in the United States from 1950 to 1964. If there are price shocks from increases in resource prices (oil, food, etc.), a wage-price spiral will upset this pattern of real wage gains.

[**] In the Carnegie-Mellon survey, responding firms placed it at 8 percent. Like most of our information on the subject, this is little more than a guess.

Rapid Technological Change and Investment

One other aspect of the relationship between implementation of new technology and employment should be briefly noted. Older plant in manufacturing industries, auto and steel perhaps, may have been rendered obsolete more quickly than anticipated. Certainly the step up in the pace of automation has generated a major increase in demand for office equipment. During the period of the changeover to programmable automation and microprocessor-based technologies, a period which may last 10 to 20 years while more versatile robots and software for office and other applications are developed, investment in the capital goods required to replace manufacturing plant that has had to be prematurely scrapped or to increase capital-to-labor ratios in offices will generate employment. High capital requirements as offices switch to electronic equipment and manufacturers use computerized machinery implies employment growth over the next two decades in industries supplying advanced capital goods. If these goods are produced in U.S. plants, growth in manufacturing jobs in these industries will, during this period, partially offset the loss of manufacturing jobs in industries where the new technologies are implemented. *The full impact of technological unemployment will not be felt until 2000.* The unknown here is the extent to which this market, both domestic and international, will be supplied by firms located in the United States. The Japanese lead in computerized manufacturing is substantial and its greater experience in successfully producing and using robots gives it an advantage in future sales of these machines. The Yamazaki Machinery Works reports more than 300 serious inquiries from U.S. companies alone.[4] American firms are better situated in the markets for electronic office equipment, home computers, electronic toys, but competition from Japan, West Germany, the Netherlands, and France is intense.[5] The growth of U.S. multinational corporations (MNCs) is a further threat to the future of U.S. manufacturing jobs in these industries. The widely scattered manufacturing operations of semiconductor firms are a case in point.

Multinational Corporations and Employment

The existence of MNCs further complicates the analysis of job loss due to changing technology. When firms were national entities and not multinational concerns, it was increasing wages of skilled workers within a country that motivated firms to seek new techniques that save labor cost by substituting less skilled for more skilled workers. The existence of MNCs with affiliates in low wage areas means that such firms have an incentive to invest in techniques that substitute less skilled Third World workers for American workers so long as the wage differential between the two groups of workers exceeds some minimum. When transportation costs for bulky products manufactured in the Third World were high, even a substantial wage differential might not have induced U.S. firms to move their fabricating operations abroad. Progressive advances in microminiaturization, lightweight materials, and transportation technology have changed that.

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[3] "The Job-Killers of Germany," *New Scientist*, June 8, 1978.

[4] *New York Times*, Dec. 13, 1981, sec. 3.

[5] *Business Week*, Dec. 14, 1981, pp. 39-120 and Dec. 21, 1981, pp. 52-54.

The ability of the developing countries to compete in the production and sale of manufactured products to the United States is only partially the result of indigenous economic development. It results as well from the growth of U.S. multinationals. The unique advantage of the MNC in comparison with national firms is its transnational ability to combine labor and material resources in the host country with technology and administrative capabilities developed in the home country. Because labor costs in less developed countries are so much lower than labor costs in the United States the possibility exists that increasing North-South trade will result in increasing specialization in production within countries with the developing countries specializing in the production of an increasing number of manufactured products. The debate over whether steel production, like black and white televisions, should be phased out in favor of imports emphasizes the immediacy of this concern. Leaving aside the issue of whether the United States should view industrial structure as an object of policy, formulating economic policies designed to achieve some structural outcome, let us consider the implications for employment as technology advances. The export of manufacturing jobs outside the United States means that productivity gains will be realized elsewhere. How much of the increase in productivity will go to increase the real wages of local workers in American-owned plants overseas is uncertain. Even if the MNC captures the entire productivity increase, it may or may not reduce the price of the product in U.S. markets. A price reduction would, of course, mean an increase in real income in the United States, which would raise demand for output and increase employment in this way. The magnitude of the effect would depend on how much of the increase in productivity the MNC keeps in the form of retained earnings (to finance expansion of its foreign subsidiaries as well as, or in place of, its American operations) and how much it passed along in the form of lower prices.

Service Sector Jobs and the Quality of Employment Opportunities

The analysis of the previous section focused on the effects of programmable automation technologies on real wage rates and on *aggregate* employment. To discuss the qualitative aspects of service sector employment growth requires that we turn our attention to how labor markets are currently structured. To begin, I want to consider the familiar thesis that investment in human capital will enable the service sector to continue expanding, so much so that it will easily absorb the workers displaced from manufacturing.[6] This hypothesis, relating economic growth to human capital formation, is a simple extrapolation of the findings of "growth accounting." In growth accounting, past economic growth is broken down into its component sources—quantity and quality of labor inputs, quantity and quality of capital inputs. The great accomplishment of growth accounting has been the identification of the increasing educational attainments of the labor force as one of the quantitatively most significant sources of growth in output per worker between 1929 and 1969.[7] However, growth accounting provides no theory to explain the nature of the relationship between the quality of labor inputs and economic growth. All that can be said on the basis of growth accounting is that investment in human capital and economic growth both proceeded at an impressive rate during the period following 1948. It is incorrect to infer that increased schooling caused economic growth from the association between educational attainment and the growth in gross national product (GNP). Service sector employment has also grown substantially during this period, though again cause cannot be inferred from correlation. In considering the ease with which displaced manufacturing workers can be absorbed by a growing service sector, two points need to be addressed. The first relates to the sex-labeling of jobs in the U.S. economy, and the second to the quality of service sector jobs.

Much of the expansion in service sector employment in the 1970's was in jobs for which women are the preferred labor force—retail sales including restaurants and fast food establishments, and health services. These are jobs that typically employ women at wages below the average in manufacturing, and that provide short hours, few fringe benefits, and little opportunity for advancement. Clerical employment was another important area of job growth. Here, again, women are the preferred labor force. Though the jobs are more varied in terms of responsibilities, opportunities, and wages paid, they are nevertheless among the poorest paid and least prestigious of the white-collar occupations. The shift to service sector jobs has largely been a shift away from jobs employing male workers and toward jobs employing females. Despite the growth in employment, high unemployment rates for women persisted throughout the decade, suggesting there was no shortage of female workers available to take such jobs. Had manufacturing employment decreased by nearly a million jobs during the last decade instead of having increased by that amount (measured from its peak in 1969 to its peak in 1979), with most of the displaced workers men, it is unclear for which service sector jobs they might have been retrained.

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[6] Eli Ginzberg and George J. Vojta, "The Service Sector of the U.S. Economy," *Scientific American* 244, March 1981.

[7] The development of growth accounting is best exemplified in the work of Edward F. Denison, *The Sources of Economic Growth in the United States and the Alternatives Before Us* (New York: Committee for Economic Development, 1962); *Why Growth Rates Differ: Postwar Experience in Nine Western Countries* (Washington, D.C.: The Brookings Institution, 1967); *Accounting for United States Economic Growth*, 1929-69 (Washington, D.C.: The Brookings Institution, 1974); *Accounting for Slower Economic Growth: The United States in the 1980's* (Washington, D.C.: The Brookings Institution, 1979).

My second point is that the growth of service sector jobs has meant an increase in both good and poor jobs. It is evident that the U.S. labor market is segmented into a primary labor market segment in which most of the "good" or "acceptable" jobs are located, and a secondary segment in which most of the "poor" jobs are to be found.[8] A further distinction can be made between autonomous primary segment jobs (professionals, like doctors, lawyers, and professors, or craftsmen like plumbers, electricians, carpenters) and subordinate primary sector jobs (mail carriers, city transit drivers, steel workers, etc.). The difference between a subordinate primary sector job and a secondary sector job is sometimes based on worker skills and sometimes on nonskill-related job characteristics. The better jobs are those in which the employer values steadiness and low turnover and is willing to reward tenure on the job with promotions and higher pay, or in which the employee is represented by a union that has won decent wages, a pay scale that rewards seniority, and protection against arbitrary treatment. Many of the subordinate primary sector jobs available for male workers are to be found in the goods producing sector of the economy, where workers have more union representation than in the service sector. This is probably the basis for the casual observation that changes in technology and the shift to service sector employment is eroding the middle of the job distribution, making the labor market more starkly two-tiered with good jobs at the top, poor jobs at the bottom, and shrinking opportunity in the middle.

The growth of the service sector has provided both good jobs and poor ones. Producer services (advertising, architecture, law, management consulting, computer, financial) now account for 19 percent of GNP, and firms in this industry have been a major source of good jobs.[9] This observation is confirmed by a Bureau of Labor Statistics (BLS) study of the computer and data processing services industry (SIC 7372 and SIC 7374).[10] This industry currently employs nearly 350,000 workers and is one of the rapidly growing business services.[11] The BLS survey found that approximately 37 percent of the nonsupervisory employees in this industry are highly paid professional or technical workers, many of them computer systems analysts, computer operators, and computer programers. At the same time, however, the survey found that office clerical employees account for another 32 percent of employment in this industry. Two-fifths of the office clerical employees are key entry operators earning $135 to $175 (Class B) or $150 to $205 (Class A) in 1978. If we calculate their hourly wage on the basis of a 35-hour week, they earned between $3.86 and $5.86 an hour. By comparison, average wages in manufacturing in 1978 were $6.17 an hour. The point is that service sector employment, like employment in the U.S. economy generally, is two-tiered. The growth of this sector has meant an increase in professional, technical, and managerial jobs at the top; but it has also meant an increase in clerical, sales, and nonprofessional service jobs at the bottom. In particular, poorly paying jobs in health services have been a major source of employment growth in the 1970's.

The number of good jobs has grown but, since 1970, it has failed to keep pace with the supply of college graduates. Employment prospects have deteriorated substantially since the 1950's and 1960's.[12] The result has been a credentials inflation in which a college degree is now a prerequisite for many jobs which could be done or previously were done by workers with a high school education. It would be incorrect, therefore, to conclude that providing an educated work force would be sufficient to guarantee the growth of jobs requiring such workers. With good jobs in the service sector growing more slowly than the supply of college educated labor, what are the prospects for workers with less schooling who in earlier years would have found employment in the manufacturing sector? Recent growth in employment opportunities in the bottom tier of the service sector suggests that, unless clerical and service workers are displaced by technology, aggregate employment will continue to grow. The available jos, however, may not provide viable alternatives for workers accustomed to decent wages and due process—union benefits and protections characteristic of much subordinate primary sector employment in manufacturing. Moreover, sex stereotyping of clerical and retail sales occupations operate to deny jobs to displaced male workers even were they to accept the low wages and authority relations typical in such jobs. Can we specify the jobs for which these young workers should be trained? The future to which they should aspire?

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[8] See Richard C. Edwards, *Contested Terrain* (New York: Basic Books, 1979); and David Gordon, *The Working Poor* (Washington, D.C.: Council on State Planning, 1980).

[9] Ginzberg and Vojta, op. cit.

[10] Department of Labor, Bureau of Labor Statistics, "Industry Wage Survey: Computers and Data Processing Services," Bulletin 2028, March 1978.

[11] *Employment and Earnings*, November 1981, table B-2.

[12] Richard Freeman (ed.), *The Overeducated American* (New York: Academic Press, Inc., 1976).

Research Needs

It should be evident from the foregoing analysis that we need detailed, disaggregated data by industry on:

1. the kinds of work suitable for automation, with currently available robots and programmable technologies and with future generations of robots;
2. the number of workers likely to be displaced, and the slowdown in growth or decline in growth of the labor force;
3. the demographic and educational characteristics of the displaced workers;
4. estimates of the average increase in average labor productivity, derived from 1. and 2.;
5. an estimate of the cost saving to be realized as a result of introducing the new technology; and
6. estimates of average labor requirements by occupation, capital requirements by type of plant and equipment, and energy requirements per unit of output at a baseline point prior to the introduction of the new technology, and at discrete intervals in the next 10 to 20 years.

Some of this information already exists in engineering cost studies of technical improvements and in other technical studies done by businesses or consulting firms, in reports of private research firms, and in case studies of individual firms. Access to these studies is sometimes limited and even the published material is not always easy to obtain. A chief difficulty is that it has not been organized into a coherent picture that would enable us to say with confidence what is known and what remains to be learned about the impact of programmable technologies. A survey and synthesis of the existing literature that identifies the gaps in what is known and is followed up with case studies and surveys taken to fill the spaces seems essential. If such a study is undertaken, it should address not only employment issues but changes in the nature of work as well. Changes in work process, management functions, and social relations within firms should all be studied for insights into changes in the quality of working life.[13] In addition, we need to know how widely used in manufacturing the programmable automation technologies will be. For firms that do not directly employ robots and related technologies, we need to know whether they will utilize capital goods produced using such technologies since this will have the effect of reducing capital costs in such industries even without a change in technique (provided, of course, that the price of the capital goods declines).

Information obtained from such case studies can usefully be incorporated into an input-output framework in order to obtain estimates of the size of the labor force, its demographic composition, and its occupational distribution under alternative assumptions about how the technology develops.[14] Final demand might be treated exogenously so that the percentage increase in various detailed input requirements per dollar of aggregate GNP could be calculated. Demand structures that hold constant, respectively, the physical and value composition of output might reasonably provide orders of magnitude for demand effects. Since the assumptions about the new technologies, or "scenarios," are necessarily subject to substantial uncertainty, ranges of plausible technology changes ought to be tested using the input-output framework to assess the sensitivity to changes in the scenarios of the qualitative shifts in demand for energy, labor, and capital inputs.

Input-output analysis refers to changes in physical quantities of required inputs per unit of output. The definitions of capital using and capital saving utilized in this paper depend on the dollar value of investment per unit of capacity. I am familiar with one study that examines that concept empirically for the Canadian economy.[15] That study, which is concerned with unemployment and only touches on the technology issues, uses measures that are aggregated for the economy as a whole. The results are not very useful for the purpose of studying technology, but the methodology is very straightforward. I have put my research assistant to work using this technique to look at particular industries and time periods to determine whether technology has been capital saving or capital using.

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[13] For a detailed exposition of the work process issues involved see Eileen Appelbaum, Kenneth Flamm, and Leonard Rapping, "A Proposed State of the Art Survey of the Literature on the Microelectronic Revolution," mimeo, June 1981.

[14] A detailed description of this methodology can be found in Eileen Appelbaum, Robert Costrell, Kenneth Flamm, and Leonard A. Rapping, "The Impact of High Technology on the Structure of Factor Demands and on the Process of Economic Growth," mimeo, March 1981.

[15] Paul Davenport, "Capital-Using Technical Change and Long-Period Unemployment in Canada, 1947-1981," *Journal of Post Keynesian Economics*, forthcoming, September 1982.

ASSESSING THE FUTURE IMPACTS ON EMPLOYMENT OF TECHNOLOGICAL CHANGE: AN INPUT-OUTPUT APPROACH

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The OTA project proposal on Information Technology, Automation, and the Workplace is an attempt to anticipate now the likely situation with respect to employment of the U.S. working-age population in one or two decades. This paper describes a methodology for quantifying the size and occupational mix of the employed labor force that will be required as a result of the progressive introduction into the various sectors of the economy of new technologies, in particular production and office automation. It makes frequent reference to a model currently being developed for this purpose at the Institute for Economic Analysis (IEA) with support from the National Science Foundation, called the IEA model.

The input-output (I-O) approach is now used in, or rather as a component of, virtually all the well-known, large-scale models of the U.S. economy like that of the Bureau of Labor Statistics (BLS) Office of Economic Growth and the proprietary forecasting models of DRI, Chase Econometrics, Wharton, and many others. I-O is valued in these applications for its ability to disaggregate overall economic activity into sectoral detail and to ensure the consistency of different assumptions made about separate parts of the economy. In this paper I will concentrate on other aspects of I-O that are generally not exploited, and I will try to address the many detailed questions about methodology, assumptions, and data that have been put to me since I agreed to participate in this workshop. I will focus on the issues that can be most readily analyzed at the present time for policy purposes but I will also indicate the research areas into which the I-O framework can and should be extended to integrate issues related, for example, to education and training into the analysis of employment and technological change.

Representing Technology and Technological Change

The technology used in a particular sector can be characterized by the mix and amount of each input required to produce one unit of that sector's output. Inputs include raw materials; various types of processed goods and of services; different categories of machines, tools, and other capital goods; and an assortment of labor skills. A technology is most concretely associated with a single production process, for example use of the open hearth v. the basic oxygen furnace for steelmaking, each requiring a different mix of inputs. Since one technology displaces others only gradually, there are generally several distinct processes in use in a given sector at any particular time and also several stages of production; the sector's "technology" is the weighted average input structure of the various processes in use. The technological structure of an n-sector economy in a given year can be described by three matrices of coefficients: the A matrix (nxn) of intermediate inputs (or interindustry transactions), the B matrix (nxn) of capital stock requirements, and the L matrix (mxn) of labor requirements, assuming m occupational categories. All coefficients are expressed per unit of output.

This description is not of course assumed to be an adequate basis for actual production: it is like the list of ingredients for a recipe which does not include the *directions* to the cook. Rather, technology is being described in terms of the demands placed by a sector on the rest of the economy.

Technology defined in this way also reflects other inputs not customarily associated with the choice of production process: "overhead" in the form of legal or personnel services or the purchase of an executive jet. The discussion of scenarios below indicates how one proceeds to isolate the phenomena of interest within this broad interpretation of technology.

A *change* in the input structure of a given sector (where inputs are measured in constant physical or value units) may reflect any number of underlying factors. In a comparison of statistically compiled historical I-O tables, it will often be necessary to attempt to distinguish the impacts of different factors. On the other hand, one purpose of designing experiments—or scenarios as they are generally called—is to isolate the changes of interest to assess their separate impacts.

Choice of Classification Scheme

The A, B, and L matrices describe the state of the economy at a given time as classified into n producing sectors and m occupations. The number and choice of categories will depend on the purposes of a particular investigation. (In many practical applications, the abilities to collect the required information and to handle large matrices will also constrain the choice.)

Sectors can be described in terms of industries or commodities:[*] if each industry produces one commodity or service and no two industries produce the same commodity or service, the two schemes are the same. The confounding factors are the presence of:

1. secondary outputs that are marketed; and
2. in-house operations (essentially "captive" production and producer services) that may, or may not, be the primary output of some other sector. These are not reported as outputs.

The commodity scheme has the advantage that the corresponding input structures are more readily interpreted in terms of engineering technology although in the presence of secondary products the "overhead" operations may be difficult to allocate to individual commodities. The IEA model uses essentially an industry classification for practical reasons: the labor and capital data and price deflators are much more readily available in that form (for historical reasons). At the level of sectoral detail of the IEA model (the 85 sectors are identified in Annex 1 along with the 54 occupational categories), industry and commodity largely coincide; the divergence between the two necessarily increases with progressive product disaggregation. Practically speaking, any scheme is a compromise between the two,[**] and it presents no particular conceptual problem to disaggregate some part of the economy more than others.

For present purposes, let us consider the case of robots which may be produced for an establishment's own use, for sale, or some combination of the two. In a commodity scheme, robots would constitute a sector which is the sole source of (domestically produced) robots for all other sectors even, say, the automobile sector, although the automobile *industry* might produce most of its own robots. In an industry scheme, the input structure of every sector that produces some robots would need to be modified to reflect the production of robots in addition to the creation of a separate robotics industry. The former is easier to implement (and is the approach chosen for this sector in the IEA model even though most other sectors are classified by industry). Both representations will lead to the same conclusions as to the effects of the use of robots on the economy as a whole and as to the total (direct plus indirect) labor requirements of each sector. They will differ in a well-defined way in the computed allocation between direct and indirect requirements of individual sectors.

If the automobile sector produces all of its own robots, the labor used in producing these robots (the vector L) is charged directly to the automobile sector (still L) will be counted as indirect. The vector L itself can easily be computed given either representation and allocated in any desired proportions between what are reported as the direct and indirect labor requirements of the automobile sector. Eventually it may be important to distinguish between the average input structure of General Motors robots and say, those produced by Unimation for other users. In this case the single producing sector would have to be disaggregated into several, producing different types of robots.

Data

The principal sources of data for the IEA model have been official government series produced by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce (input-output tables and capital flow tables for 1963, 1967, and 1972) and by BLS (industry-occupation matrices for 1960, 1970, and 1978 and industry price deflators). The sources of these data are given in Annex 2.[*] We have relied also on manual and automated search of the open business and technical literatures, reports of private research organizations, and some interviews and informal surveys.

There is no substitute in terms of scope and comprehensiveness for the official data. At the same time many of their limitations are well known and have been described in various places. For example, a great deal of effort has been expended at our Institute to render the data tables *compatible* with respect to assumptions and classifications.

The official I-O and capital flow tables can be considered accounting type data in terms both of their basic sources and the methods used in compiling them. Relatively little use is made of technical sector experts in evaluating the input structures (i.e., table columns); this is one objective of the IEA case studies described below.

There is no concrete concept in the official data of output units for the so-called service sectors; consequently many of the associated price deflators are largely arbitrary.[**] This situation makes it hazardous to analyze the changing position of the non-goods-producing sectors, which broadly defined already employ about two-thirds of the labor force, based on these tables. In attempting to make some progress in this area, we have concentrated first on the education sector: it is a large employer, it is the source of training and retraining, and it is easier to improve than most of the other service sectors. We have redefined the unit of output and disaggregated public education from health care and nonprofit organizations in the capital flow tables using fragmentary information from government studies and the other types of sources indicated above.

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[*] An industry in this usage is the set of establishments that produce a given principal output: they may in addition produce (the same or different) secondary outputs.

[**] The sector including mills producing two slightly different grades of paper could be considered an industry with a secondary product. Alternatively, it could be considered a single commodity.

[*] Historical data have been assembled because the model will also be used to examine the period from about 1960 to the present: they are not used to extrapolate the structure of the economy in the future from a time series description of the past.

[**] It might be pointed out in a discussion of price deflators that for other reasons the official deflator for computers implies no change in real price over the past two decades. We have instead assumed an average annual *decrease* of 10 percent which more accurately reflects the already steep increase in their use.

The capital flow tables compiled by BEA would be even more useful if sector experts brought more *information* to bear on the present methods of allocating a particular capital good among using industries. The official data on capital *stock* requirements by using industry distinguish only between plant and equipment. A detailed breakdown by type of capital based not only on deduction from flow data, but including direct survey, should be a high priority objective. We have constructed very tentative stock matrices for the IEA model based on the capital flow tables.

The IEA model will make use, through its case studies, of the available business and technical literature and the data and reports of private organizations, which contain a wealth of information but require a great deal of effort to piece together into a coherent picture. An example of this source of information is the "composite forecast" prepared in electronic and hard-copy form by Predicasts, Inc.: an illustrative table describing robots in the U.S. market is shown in Annex 2. Not surprisingly a number of vendors of detailed economic information either use or have expressed active interest in using I-O both as an organizing device and to improve the consistency of a great quantity of numbers taken from diverse sources.

Information for describing, for example, a robot sector, which had little economic significance in the year of the most recent official tables (1972), was pieced together from other sources including the items referenced in the Predicasts forecast mentioned earlier and informal interviews and written surveys by our own staff of knowledgeable individuals willing to cooperate, for example the president and the manager of personnel of a major producer of robots. This type of survey is also the basis of the so-called ex-ante I-O tables compiled by the Battelle Memorial Institute in a more formal and standardized fashion.*

Case Studies

Any model that uses an I-O module has at least indirectly to be concerned with the representation of technology and technological changes, but typically this concern is indeed indirect. The historical data are usually accepted as given in the official sources. The coefficients describing the structure of the economy in the future are generally estimated by a formal statistical procedure with little effort at interpreting the technical structure implied by it. In most cases where an I-O module is used to disaggregate the projections which have been made by an aggregate econometric model, technological change is not at the center of attention.

The case studies being carried out at IEA vary in scope and depth but have a common purpose: to *evaluate and improve* the corresponding portions of the available historical I-O type data (i.e., A, B, and L matrices) and to *project* these data to the future on the basis of alternative assumptions about structural change in the sector under study.

Two of the case studies carried out at IEA on robotics and education have already been mentioned; others include the chemical, iron and steel, automobile, textile, and health care sectors, and telecommunications, office equipment, and computers are in progress. The robotics study, for example, includes a compilation of current, capital, and labor input vectors for the U.S. robotics producing sector circa 1990. In addition, it projects the level of robot purchases for 45 likely using sectors. In each using sector, seven occupations in which workers are likely to be displaced by robots and two which will be required in greater number because of robots, are identified. The percentage change in labor input requirements (for each occupation in each using sector) is projected under alternative assumptions. The quantitative output of the case study is the direct input to the computer programs.

The Dynamic Model

The basic objective of an I-O analysis of the impacts of technological change on employment is, in operational terms, to quantify the levels of detailed labor inputs which will be required in a given year to satisfy any given level and composition of final demand, making alternative assumptions about production technologies (i.e., using alternative A matrices). In an open static model, the level and composition of final demand, which includes private and public consumption and investment and net exports, are *exogenous;* they are implicitly assumed to be relatively independent of the technologies in use. Almost all empirical I-O analyses have been carried out within an open static framework.

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*The Battelle tables are based mainly on surveys of engineers. We have for various reasons not been able to make use of these tables for ongoing Institute work but consider them a valuable source of information—and, more important, a valuable methodology—for use in future work.

In a fully closed dynamic model, at the other extreme, the different components of final demand are explained *endogenously*. For example, trade flows in the IEA World I-O Model are parameterized by means of region- and commodity-specific import coefficients and export shares, and the levels of imports and exports are thus computed endogenously. (In the open model one can—at least in principle—using alternative assumptions concerning the exogenously determined exports and imports, *approximate* changes in the structure of foreign trade that are taken care of automatically (i.e., endogenously) in the closed model.)

The present version of the IEA model represents a significant advance in the endogenous determination of investment.* In experiments carried out with this model, investment will be governed by a B matrix associated (in terms of technological considerations) with each A matrix. Exogenous final demand will *exclude* private fixed capital formation which will instead be computed endogenously to satisfy in level and composition the production of a particular final bill of goods. This means of course that the labor required to produce these investment goods will also be appropriately computed.

Scenarios

A scenario is an experiment carried out within the framework of the model to address a specific question. The starting point is a description of the I-O structure of the economy (i.e., A, B, and L matrices) for each year in the time horizon under examination, and each scenario consists of specific alternative assumptions about how that structure (i.e., the individual coefficients in the A, B, and L matrices) might evolve. The size of the labor force and its composition by occupation as implied by each scenario are then computed (along with many other variables) and can be compared across scenarios. It is standard practice to define a baseline scenario for purposes of comparison. In the IEA model the baseline scenario assumes that the present I-O structure of the economy remains unchanged in the future.**

Scenarios may differ in their assumptions about virtually any aspect of the economic structure. I will briefly discuss some possible scenarios about the rate of adoption of automation, the identification of the occupations affected and quantification of the impact on individual labor coefficients, and the level and composition of final demand. These are the types of scenarios that can be most readily computed at the present time. As the model is progressively "closed" with respect to other components of final demand, a scenario approach will also be used to represent alternative assumptions about the constraints under which the economy operates.

In order to represent the use of programmable automation, it is first necessary to distinguish in physical terms the types of automation equipment in question, by what combination of existing and new sectors it will be produced, and the input structure for production. Then, depending on the case, it is necessary to identify the sectors and/or the operations in which this equipment may be used and the likely level of use. The occupations of workers that may use both the automated equipment and that which it complements or supersedes must be specified, along with other affected current and capital inputs of the using sector, on a per unit of output basis. All the assumptions must of course be quantified. A standard set of assumptions for 1990 is produced by the associated case study and "spliced" into the A, B, and L matrices for that year and for prior years as required: the actual splicing consists of course of replacing equipment and the corresponding input flows, including labor inputs, per unit of output of a particular sector by new equipment (e.g., robots) and input flows, including labor, required (also per unit of output) by the new technology. (Note that the incremental output—and labor—required in *prior* years to produce the capital in place in May 1990 will automatically be computed.)

The "standard" assumptions referred to in the preceding paragraph reflect the combination of what we consider to be the *moderate* projections of experts dealing with different aspects of, say, robotics. Alternative scenarios incorporate more extreme views, either hypothetical or actually expressed by other analysts. (In later stages of our research, the portions of the case studies dealing with the future will rely increasingly on *technical* factfinding; this work will make possible the elaboration of more detailed, technical scenarios.)

Sample robotics scenarios for which preliminary computations have been made include:

- What will be the level and occupational composition of employment in 1990 implied by the standard assumptions of the robotics case study compared to the baseline scenario (assuming in both cases the same projected 1990 final demand bill of goods and the same state of the economy in 1980)?

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*A model in which investment is endogenous can be considered a dynamic model. Many models have been called dynamic; in the dynamic I-O model, capital flows and stocks are disaggregated by producing and by using sectors, and the framework requires not only intersectoral but also intertemporal consistency in the production and disposition of the highly disaggregated capital stock.

**"Present" here means the most recent year for which official accounting data are available; I-O and capital flow tables for 1977 should be available in the near future.

- What if one additional mechanic is required for every three robots instead of every six robots in each using sector?
- What if each using sector acquires twice as many robots as under the standard assumptions?

Scenarios will also be developed for office automation involving changes in the use of telecommunications equipment, computers, and office equipment by clerical and certain categories of managerial and professional employees in all sectors. Production automation, involving essentially computers and sensors (as well as robots), includes process control, computer-aided design and manufacturing, inventory control, and scheduling. While the latter case study is more complicated, the investigation will follow the same approach. Scenarios will specify values for the amount of use and the impacts on individual I-O coefficients of different forms of automation, singly and in combination.

The following type of scenario is included to give a concrete idea of the range of questions that can be addressed in the near future with the present model and expanded effort on the case studies:

- The different case studies deal with the introduction of specific types of automation equipment into specific operations. Assume that all aspects (that have been identified) of production and office automation proceed at a "moderate" pace over the next 10 or 20 years. How will the size of the employed labor force evolve? Which occupations will experience the slowest growth (or greatest decline)? What will be the demand for computer programers?

Policy and Research Issues

For policy purposes it is necessary to have a model that can produce results quickly and inexpensively. This can be achieved if:

1. there is a methodology for preparing at least certain types of scenarios quickly by human analysts, and
2. the computer software is designed (among other considerations) to process an entire scenario as a single input.

The section on scenarios describes the types of scenarios for which these two considerations can be met most readily. The software design issues are well understood.

The case study approach has been developed to provide the required format for scenarios, and improving the scope and depth of the case studies should be a high priority. In fact, "micro" studies now sponsored by the policy community for more general factfinding purposes could be guided to include a section structuring the information content into a format that would permit its being used directly by a model such as the one described.

In subsequent work on technological change, the IEA model can and should be "closed" with respect to trade, accomplished by integrating it into the World Model. This will make it possible to analyze a considerably expanded range of policy scenarios where U.S. production is directly linked to its trading partners' economic activities. In the open system, these impacts are instead approximated by *hypothesizing* changes in U.S. imports and exports.

From a research point of view, there are many avenues of work that would improve the accuracy of the projections of the basic model (without even touching for present purposes on the important area of computational research).

Additional basic research is required to make further conceptual advances toward a fully dynamic I-O model in addition to the critical need for better data on capital flows and especially capital stocks, on a disaggregated basis.

The other important area for further work is the incorporation of a demographic model into the dynamic I-O model. This would provide the basis for improving and rendering consistent the projected demand for education and health care as well as other components of household consumption.

THE EFFECT OF TECHNICAL CHANGE ON LABOR

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Summary

Technical change, which makes possible the production of more output from a given amount of resources, is a major contributor to increases in society's well-being. The very process of change may, however, impose hardships on those who use old and no longer efficient methods or produce products that are no longer wanted. The net effect of technical change on labor is hard to predict. Workers, as consumers, gain from increases in productivity; they are able to buy things at lower prices. If they cannot adapt to new production methods (and lose their jobs as a result), they can end up as net losers.

Not only is the effect of technical change on labor hard to predict, but technical change itself is hard to define and measure. It cannot be measured simply as the installation of new (and different) equipment. Nor can it be measured solely as the growth of productivity. All three—technical change, new equipment, and productivity growth—are related. A goal of this paper is to clarify the relationship.

It is important, at the start, to distinguish technical change resulting in the appearance of new products from a change in production processes. To some degree, this distinction is artificial; programmable automation equipment is a new product of industries producing capital goods, but its use represents a new process in other industries. Both new products and new processes can affect labor. The development of a new product—passenger aircraft—and new processes—assembly-line methods of production of automobiles—led to increases in employment in those and a host of related industries—home construction, leisure products, etc. At the same time, workers in other industries— horse-breeding, saddle-making, the rail passenger industry—were being squeezed out into other jobs. Now, changes in production technology, here and abroad, are leading to a reduction in employment in auto production and autoworkers are having to adjust.

We analyzed the effects of technical change on workers in two steps. The first step is to estimate the effect of technical change on an industry's employment. We concentrate on the effect of new process innovations since these are likely to have more concentrated impacts on employment. The next step is to estimate the effect on individual workers: How many workers are displaced during the adjustment process? How long does it take them to find new employment? How much does displacement affect their earnings?

The Industry Cost Model

To determine industry effects, we use an econometric model of cost in which cost is assumed to depend on the prices of factor inputs, the level of industry output, and the level of technology. This is the standard analytic approach in economic studies of technical change. The rate of growth of total cost is composed of the weighted average of the rates of growth of input prices, a weighted rate of growth of industry output, and the rate of cost reduction due to technical change. Technical change is therefore only one determinant affecting industry cost; input price changes, for example, may be more important.

We included five factor inputs—production labor, nonproduction labor, capital, energy, and materials in the cost function and imposed no restrictions on how they can substitute for each other. We assumed cost minimization and estimated how technical change has affected the steel, auto, and aluminum industries. The model was estimated at the four-digit Standard Industrial Classification (SIC) category, a finer level of disaggregation than that used in most industry studies.

One of the advantages of using this kind of model is that with relatively few variables, much can be learned about factor substitution, input adjustment, and the effects of technical change. Data on input quantities and prices, industry cost and real output, and the level of technology are almost all that is needed. Data needed to measure capital and technology is often difficult to find, but the model clearly specifies what is needed for estimation.

Equations in the econometric system illustrate important relationships. For example, equations that express the dependence of each input's share in total costs on all input prices, output and technology may be used to describe how input-output coefficients, which are measured similarly to input shares, move over time. More important, the equation also describes why they move. It explains changes in input-output coefficients in terms of: 1) adoption of new techniques, 2) changes in input prices, and 3) changes in scale.

For labor, the equation describes how changes in labor's share (i.e., the ratio of payroll to total cost) depend on changes in the wage, other input prices, output, and the level of technology. The effect of any variable on labor's share is obtained from the regression estimates. For example, the effects of technical change, holding prices and output constant, is described as labor saving, using, or neutral if the parameter on technology is negative, positive, or zero. Labor-saving technical change means that as technology increases, the share of payroll in total costs goes down. The estimated equation can then be used to derive the effect of technical change on the demand for the *quantity* of labor.

Another equation in the system may be used to explain the relationship between the rates of technical change and productivity growth. Productivity growth is measured in terms of total factor productivity rather than labor productivity, which is only a partial measure of input use.

The rate of productivity growth has two components. The first is the rate of technical change. The second depends on the relationship between changes in industry cost and output changes. Most researchers assume that, in longrun equilibrium, industry cost and output change proportionately. This assumption, called "constant returns to scale," is often imposed on the equations. If this assumption is correct, then this second component of productivity growth becomes equal to zero, making the rates of productivity growth and technical change equivalent. Thus, low rates of technical change would imply low rates of productivity growth.

We feel, however, that constant returns to scale is too strong an assumption. Certain factor inputs, like capital and nonproduction labor, may be "fixed;" they cannot be adjusted quickly without incurring large cost. Because of these fixed inputs, costs do not change as much as output. This means that studies that simply impose constant returns to scale, thereby disregarding the second component of productivity growth, will overstate the effects of technical change.

The Measurement of Industry Technology

Thus far, we have illustrated that technical change is only one determinant of industry cost changes and one component of productivity growth. We have not yet related technical change to the introduction of new technologies.

To do this in an econometric model required measurement of the level of industry technology. The standard approach is to represent the level by a time trend. This is satisfactory if changes in technology unfold regularly and gradually. It is unsatisfactory if new processes are introduced rapidly, that is, within a relatively short period of time. This distinction is important since sudden or unexpected shifts in production processes and labor demand may make adjustment difficult for the industry's work force.

To be as precise as possible, we therefore constructed direct measures of steel and auto technology. (A measure for aluminum could not be constructed.) For steel, the measure was based on the use of the basic oxygen furnace, which is important in the steelmaking process. Technological innovation in the auto industry since World War II has proceeded under the term "Detroit" automation. The term refers generally to the substitution of machines for workers in actual production processes, such as welding. To quantify the concept of automation, we measure the stock of transfer machines, the basic unit of Detroit automation.

Empirical Results of the Cost Model

In our empirical work on steel and autos, we compared the precise "direct" measure with the simpler time trend. The findings were about the same; the use of the direct measure added little precision to the estimates of the effect of technical change beyond what we estimated using the time trend. Regardless of how technology was measured in steel and autos, estimates of the rate of technical change in the industry were similar. We found the average rate of technical change to be virtually 0 percent in steel. It was just under 1 percent in aluminum, where little new process innovation has been observed, and 1.50 and 2 percent in autos (the higher figure was for the time trend version). These findings illustrate the tenuous connection between new process innovation and technical change.

The effects on input demand are similar across industries when the time trend is used to represent technology. We found that technical change was labor saving and capital using. This meant that, holding input prices and output constant, labor's share was decreasing over time while capital's share was increasing by about the same amount. In autos, in the 1970's, labor demand decreased by about 4 to 5 percent a year.

When direct measure was used, the results for steel were about the same as when the time trend was used. For autos, there were some differences from the time trend regression. There were smaller negative effects on labor and smaller positive effects on capital. One tentative interpretation of this is that advances in technology meant that newer capital was more productive than the capital it replaced and that it used only slightly less labor.

In summary, we found that the effects on employment of introducing new technologies, whether measured directly or by a time trend, were indeed negative but occurred gradually. We did not find evidence of abrupt changes in the demand for labor. Some of the empirical estimates differed according to how technology was measured, but the implications for employment adjustment were essentially similar. Given these similarities, the time and expense of creating direct measures seem unnecessary. The exploration of other issues may prove more fruitful in determining how new technologies affect employment.

As an example, our findings point to an interesting implication of the generally labor-saving and capital-using effects of technical change. When the price of labor increases relative to capital, little short-term substitution of capital for labor takes place. Over the long term, however, the use of advanced technologies allows capital to be less labor intensive and so the quantity of labor decreases relative to the quantity of capital. This possible "induced innovation" has been difficult to identify empirically. Generalizations of our model may help quantify the link between new technologies and their determinants.

The Effect of Employment Reductions on Workers

We have taken our analysis further than simply examining the effects of technical change on aggregate employment. We have also examined:

- the extent to which employment reductions can be accommodated through attrition rather than displacement, and
- the earnings losses of displaced workers.

Displacement Findings

Our results are that attrition varies widely across industries, from about 5 percent per year in high-wage industries (steel) to about 65 percent in low-wage industries. If high-wage, low-turnover industries, such as steel and autos, had to reduce employment by 5 percent in a given year, about two-thirds of the reduction could be accommodated by attrition under average conditions. If employment had been increasing prior to the reduction, attrition would be higher, that is, more than two-thirds would be attrition. If employment had been falling, attrition would be a lower proportion. This is because attrition is primarily determined by the tenure structure of the industry. Attrition, which is extremely high among recently hired workers, falls dramatically after a year or two, and is extremely low thereafter until workers near retirement age. Recent hiring and layoff patterns cause large swings in the proportion of the work force that is most likely to leave voluntarily, and this, in turn, causes swings in the attrition rate by as much as 2 percent.

Aside from their effect on the tenure distribution, general business conditions (the business cycle) have little effect on attrition. Although other studies show that the quit rate is sensitive to changes in business conditions (and quits are the major element of attrition), those studies generally ignore the changes in the tenure distribution over the business cycle (use imperfect measures of tenure structure). Instead, they rely on aggregate turnover statistics that show a fall in quits during recession simply because workers who would otherwise quit are laid off.

A 5 percent employment decline cannot be fully offset by a 5 percent attrition rate. There will be some displacements because the employment change across firms is not uniform. Even while total employment in the industry is declining some firms will be expanding. Attrition in the firms that are expanding must be replaced by hiring and obviously cannot count against the net decline. The dispersion of firms around the mean employment change is substantial, so that even where employment in the industry is constant, about 1 percent of the employment industry's labor force will be undergoing displacement.

The existence of a more-or-less constant background level of displacement is important. Displacements are most costly when they are entirely unexpected. If workers anticipate a nonzero probability of displacement, they can prepare for that eventuality and reduce its consequences. This appears to be the case in some high-wage industries such as aerospace, which have major boom and bust cycles as a result of military and civilian aviation procurement policies.

Plant closings are a major source of displacements because attrition can do little to offset employment declines when plants close. Closings are particularly likely when a firm experiences a sharp decline in demand: below a certain level of production, it is simply uneconomic to stay in business.

Earnings Loss Findings

Earnings losses due to displacement are highly correlated with attrition rates—high losses go with low attrition. This makes good economic sense; if few workers are leaving voluntarily, this is strong evidence that there are few good alternative jobs, and a worker who is forced to leave will have large losses. Displaced workers experience a transitional period of earnings losses due to lengthy unemployment (a good part of which may be simply waiting until all hope of recall vanishes*).

When workers begin to search for work, they often will try out several jobs until they find suitable employment. Workers' earnings then begin to rebound but usually, in cases where initial losses are high, they never fully catch up with what they would have earned had they not been displaced. The "permanent" loss is generally between 7 and 15 percent of annual earnings and amounts to about 50 percent of the total earnings loss. (The total loss in industries such as steel and autos is generally equal to about 2 year's earnings.) The transitional loss is about equal to the permanent loss, but it lasts only a year or two. The temporary loss, however, is more likely to be offset by unemployment insurance, SUB, and severance pay.

In analyzing earnings losses, we measured how they vary with respect to age, tenure, labor market characteristics, and the size of the employment decline. Again, tenure was a key determinant of the size of the loss. New hires and workers close to retirement experience small losses, while other workers tend to have large losses. The largest losses occur among workers with about 5 years experience. This is because they have many years over which to accumulate the permanent part of the loss, and because they may be in a position to assume more responsible positions but do not yet have the experience needed to convince another employer that they are ready for such a job.

Labor market characteristics are also important. Loss in the transitional period can be doubled if displacement occurs when area unemployment is high (one standard deviation over average—about 1.3 percentage points). Losses are substantially larger if the displacement has occurred in a small labor market and marginally greater if a large number of similar workers are searching for work. Workers who have been displaced because of a plant shutdown do not have much larger losses than similar workers displaced under other circumstances. A shutdown will, however, displace higher tenure workers who have larger than average losses.

Methodology

This section discusses, in general terms, the methodology used to obtain the above results. The details are discussed in the reports referenced at the end of this paper. The basic estimating equations used to examine attrition and earnings loss are quite simple. Attrition is assumed to be a function of worker characteristics—age, race, sex, tenure, earnings level, and the rate of change of earnings; plant characteristics—employment level (size), employment trends, whether part of a multiplant firm, average wage rate, and trend of wages; and labor market conditions—stage of the business cycle (current unemployment rate divided by the rate at the previous trough), size of the labor market, recent growth rate, average wage rate, and measures of industrial diversity.

Earnings are estimated as a function of many of the same variables used to measure attrition. Prior earnings, however, is the key determinant, since it captures the way in which a host of determinants, which remain more or less constant over time (such as education, health, and marital status) affect a worker's earnings potential. The earnings equations are designed to compare the earnings of displaced workers to those of similar workers who are not displaced but are initially employed in the same industry. Econometric tests are applied to ensure that the equation matches the earnings of the two groups exactly.

The procedure for estimating how employment changes are distributed across firms in an industry is more complex. We assume that units use a strict LIFO (last-in-first-out) displacement rule. Given this assumption, the seniority distribution of displaced workers is also the cumulative distribution of employment changes across all the individual units. The actual seniority distribution is calculated by observing the tenure of displaced workers and relating tenure to seniority. This procedure is used to examine displacement under a range of circumstances and then econometric techniques are applied to generalize the results.

Data

All three estimating procedures are carried out with the same data set—Social Security's Longitudinal Employer-Employee Data (LEED). These data contain the age, race, and sex of a continuing 1 percent sample of the work force, each individual worker's quarterly earnings from each employer, and the employer's industry, location, and firm size. The data cover the years 1957 through 1975. Job changes are noted by a change in the employer who files a quarterly earnings report for the worker.

A key problem is that there is no explicit indicator of the reason for separation in the data. Thus, we must infer whether a worker who changed jobs was displaced or left voluntarily (attrition). To measure attrition, we isolated a sample of workers who changed jobs when employment in their plant (or sometimes area) was increasing or stable. We assume that under such circumstances, no displacements were taking place. The earnings loss due to displacement is estimated using a simultaneous equation approach that compares the earnings loss of leavers in firms where employment is growing or stable to the loss of leavers in firms where employment is falling. It is thus possible to net out the effect of attrition from the effect of displacement. In practice, it turns out that holding constant the other factors mentioned earlier, earnings reductions are relatively insensitive to whether displacement or attrition was the reason for the job change; both the displaced and voluntary leavers have similar earnings reductions.

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*A large fraction of workers laid off eventually are recalled. In fact, temporary unemployment is the largest component in the cost of an employment reduction, but the cost is low per capita, and industrial workers generally anticipate several episodes of substantial temporary unemployment.

The LEED file is not the only data base suitable for estimating earnings losses. We have also used data from State employment security agencies (UI offices). These data include wage records that closely resemble those in the LEED file, but they also include information on the worker's receipt of unemployment compensation, last day worked, occupation (in some cases), and the reason for separation (if the worker claims UI). Thus, these data contain a richer set of variables. A major value of these data is examining the extent to which transitional losses are offset by the receipt of UI. For example, we recently used data of the type to study TAA (Trade Adjustment Assistance) recipients in Pennsylvania and concluded that more than 50 percent of the transitional loss in earnings is replaced by UI benefits.

Summary and Conclusion

Our research on the effects of technical change on employment has been aimed at measuring technical change and its effects on labor in the steel, auto, and related industries. State-of-the-art econometric models were used to determine the effect of technical change on employment and to measure how displaced workers adjust.

Our basic conclusion about the effect of technical change on employment is that, while technical change was labor saving, it occurred at a steady and relatively slow pace. It appears that new technologies were adopted principally to avoid increases in labor costs.

Detailed description and measurement of the installation of new technologies, such as transfer machines in autos and the basic oxygen furnace in steel, seems no better than the time trend in measuring how technical change affects employment. This reinforces our conclusion that technical change in established industries (process innovation) is slow and steady.

We also linked technical change in one industry to its effect through factor prices on the other industries. This allows comprehensive measurement of the net employment effect of innovation. Although technical change in steel reduced employment in the steel industry, the change in steel *increased* employment in autos by reducing the price of a key input.

Our models have been carefully checked and tested for sensitivity to key assumptions. They represent a good way to measure the effect of technical change; the same methodology can successfully be used in future research. In particular, we believe tracing the effects of individual technologies is not worth the high cost. The effects of changes in consumer preferences, factor prices, and foreign competition on labor demand are likely to be far more important and can change far more swiftly than production technology, as we learned in the 1973 oil embargo. One fruitful extension of this approach would be to investigate the determinants of technical change itself, such as the extent changes in factor prices induce factor-saving technical change.

We have also analyzed how employment reductions affect workers employed in a given industry. Employment reductions are costly to labor primarily when workers are displaced from established jobs, but reductions that do not result in displacing workers are almost costless. The work, therefore, addressed how employment reductions are distributed across plants and how much of the reductions can be accommodated by attrition. The cost to displaced workers was also assessed.

Our basic conclusion is that employment reductions can be handled largely through attrition. The main threat of dislocation is from plant closings. Although major plant closings occur rarely, we calculated that they are responsible for half the displacements in the steel industry. Our work on earning losses showed that when potential losses are large, the attrition rate is low. Thus, in industries where few workers leave voluntarily, such as steel and autos, major employment reductions are likely to be very costly and can involve substantial displacement. On the other hand, employment reduction in high turnover industries, such as textiles and apparel, have minimal adverse effects on workers.

In terms of future research, further work on attrition is called for. We found that attrition is largely a function of the tenure structure in an industry, but other research suggests that cyclical conditions are a key determinant of attrition. Although these two explanations are not necessarily contradictory (the tenure structure changes as a result of cyclical hiring and layoffs), it is important to determine whether bad business conditions reduce attrition holding tenure structure constant. If, contrary to our evidence, attrition falls in a recession because general business conditions worsen, we will have overestimated an industry's ability to adjust to employment reduction without displacing many workers.

A second objective of future research is to explain why workers, in industries such as steel and autos, suffer such large losses and what government can do about it. There is a widespread feeling that these losses are an indication of a failure in the functioning of the labor market. In the extreme form, it is assumed that displaced workers "fall off the end of the earth" and never adjust. Competing explanations are that the earning reductions represent normal job search costs plus loss of high wages attributable to unionization or specific human capital.

If market failure is responsible, an effort should be made to determine its cause. If specific failures can be isolated, there is a reasonable chance that government action can help eliminate them at low cost. If loss of union protection or human capital are involved, policymakers should recognize the constraints this implies.

Our evidence is that where losses are large, displaced workers adapt to new jobs but never regain the earnings level they would have attained had they not lost their jobs. The adjustment is painful; often 50 percent of the loss occurs in the first 2 years. The "permanent" loss is about 7 to 15 percent, about that estimated for union/nonunion wage differentials. This evidence is consistent with the hypothesis that losses are due to loss of union protection or specific human capital. If this view is correct, a policy that will fully eliminate the loss must raise the income of an experienced worker about $2,500 a year or about $40,000 in present value terms. Thus, any government actions to eliminate losses such as training or enhancing unemployment insurance will be expensive.

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PROGRAMMABLE AUTOMATION: ITS EFFECT ON THE SCIENTIFIC-ENGINEERING LABOR MARKET

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Adjusting to Technological Advancement

Introduction: An Analytical Framework

Technological change and innovation play a predominant role in productivity and general economic growth. They also create shifts and movements in the supply and demand for labor. In particular, they are presumed to require the labor force to adjust or respond to demands for alternative knowledge and skills. Generally, the theoretical construct for determining the supply and demand for labor (or the impact of technological change on shifts in supply and demand of labor) is the production function (6). This function (whether Cobb-Douglas or C.E.S.) expresses how the final product (output) is a function of inputs (for simplicity, capital, and labor) and how the inputs are related. For example, the marginal product produced by capital or labor is derived by differentiating the production function by either input. As either increases its marginal product (ceteris paribus), the demand for its services increases over the other.

The relationship of inputs to outputs, and inputs to inputs are influenced heavily, however, by the existing technology. Technological change, in turn, alters these relationships in several important ways—including changes in: 1) the efficiency of technology, 2) economies of scale, 3) capital intensity, and 4) elasticity of substitution. Moreover, technology change either is neutral or nonneutral. Neutral changes in technology affect technological efficiency and technologically determined economies of scale. These alter the relationship of inputs to outputs. Nonneutral changes, on the other hand, affect the intensity of technology between inputs. An increase in capital intensity is labor saving when capital is a more rapidly growing factor of production than labor. "Many economists have the feeling that technological change has been quite labor-saving, but they generally acknowledge that the evidence is indirect and too weak to permit a clear-cut judgment" (12).

A further dimension to the production function analysis is found in what has been termed embodied and disembodied technological change (17). The former generally refers to actual physical changes in the capital equipment being operated and assumes that it becomes more productive. The latter concept is usually characterized by managerial or organizational changes which cause the interaction of capital and labor to be more productive. Generally speaking the analysis of programmable automation can be treated as embodied technological change. In summary, the production function framework suggests that embodied technological change raises the marginal productivity of capital relative to labor. It does this through increasing the intensity of technology and the elasticity of substitution. Thus, everything else constant, the demand for labor shifts. For the most part, such shifts cause the substitution of capital for labor, and/or one type of labor for another.

Postschool Education, On-the-Job Training, and Turnover

Although the production function offers a useful framework for conceptualizing the impacts of technological change on the demand for labor, our present interests require us to go beyond this framework. We seek a framework that explains the type and level of human capital adjustments made by labor as the demand curve for specific skills is shifted by embodied technological advances. The widely applied theory of investment in human capital lends itself well to economic choice modeling and to an analysis of earnings. The theory takes a labor supply perspective. Workers make decisions about their labor force behavior in response to the derived demand for alternative skills or knowledge. Thus, demand conditions are given and the supply of workers responds. Human capital theory maintains that worker response is in the form of income maximization over the working life. Since derived demand is dynamic, labor supply is dynamic. What may have been a good decision previously may become a poor one later if the worker does not adjust to changes in demand. According to human capital theory the incentive to adjust (or not adjust) primarily is pecuniary. In effect, the theory holds that a person makes an investment of resources in upgrading his or her productivity. Couched in the marginal productivity thesis, workers get paid the value of their productivity. Consequently, increases in productivity are assumed to lead to increases in income. Since the investment of resources (primarily foregone earnings) is costly, individuals weigh the present value of the increased flow of future income against the present value of the cost of the investment. Income maximizing individuals will make investments in those alternatives with the highest rates of return.

The theory is an exact interpretation of very inexact reasoning on the part of individuals. The theory has received much criticism, especially for its simplicity of the "economic man" concept (ignoring the nonpecuniary incentives of selecting occupations or furthering education—at least in empirical work). However, the concept of maximizing utility readily fits into the investment framework. It is the measurement of nonpecuniary returns that eludes the researcher. The theoretical framework is a useful one for the present analysis because it explains behavior as a function of price (cost and earnings) and it encompasses formal educational training (both early and later in the career), on-the-job training (OJT),* quit behavior, and occupational changes.

Although not fully developed at this point (nor widely embraced by economists) "implicit contract" theory promises to improve our understanding of labor market adjustments (1,2,3,8,9,11). The implicit contract framework addresses better the employer's part in the human capital investment decisionmaking. In particular, it addresses the decision of the firm to provide OJT and to influence turnover. Succinctly, because workers are more risk averse vis a vis employers, employers are willing to provide more stable employment and less risky OJT investments in exchange for lower wages. Without developing the theory more fully here, let me emphasize that an examination of labor market adjustments to technological change should consider employer as well as worker decisionmaking.

What kind of alternative choices do workers and employers make when rapid advancements in technical knowledge and skills lead to obsolescence? For scientists and engineers (S/Es), these choices include reading professional and trade literature, participating in workshops and conferences, returning to school (part- or full-time) (10), investing in formal and/or informal

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*Editor's note: OJT is more broadly defined in this paper than in ch. 3 of the text where it refers only to informal skill acquisition.

OJT, and changing jobs. Changing jobs includes both changing employers and/or changing occupations (either within or out of S/E occupations). Employers, likewise, have alternatives for retooling their work forces experiencing obsolescence. Primarily, these options include providing informal and formal OJT, reassignment of job tasks, and laying off workers with obsolete human capital (and, in turn, recruiting new talent).

Investment decisions made to replace obsolete human capital probably are influenced most strongly by age, which affects investment behavior in several ways. In its simplest form the relationship between age and investments is considered dependent on the time horizon for receiving returns. Older persons simply invest less because they have fewer years to receive investment returns. For the same reason, employers restrict opportunities for older workers. Secondly, investments will decrease at an increasing rate with age if older workers become less efficient in producing human capital. Ben-Porath addresses this possibility in testing his "neutrality hypothesis." The neutrality hypothesis assumes that the efficiency of human capital production and market production remains constant throughout the career. Any shift in efficiency towards the production of goods and services in the product market reduces the likelihood of producing further human capital.

A third dimension to the relationship between age and investment probabilities is deterioration. Like physical capital, human capital can deteriorate over time as a result of obsolescence and/or depreciation. According to Rosen (16), obsolescence indicates that more vintaged knowledge has become outdated by more recent knowledge. This can be caused by advancements in the sciences, production innovations which render existing skills useless, and the "increasing abilities of successive generations." Depreciation, on the other hand, indicates a loss of ability by individuals to apply their existing knowledge and skills. This presumably goes hand in hand with age as physical and mental capacities diminish.

Although most modeling treats obsolescence and depreciation as one (usually a depreciation factor), the distinction between the two is especially important to the study of S/Es where technological and scientific advances make relatively specialized skills obsolete more quickly. To keep abreast of these advancements and to at least protect themselves in the labor market, scientists make further investments in their human capital stock. In contrast, depreciation reduces the capacity to apply one's stock of human capital to production, which reduces the rates of return to further investments, and, thus reduces investments.

Other important determinants of investment behavior for S/Es include education level, labor market conditions, years of experience, tenure with present employer, sex, and government contracting. When the determinants of investment behavior cause disincentives to retooling obsolete skills, S/Es are more likely to change employers, occupations, industries, and incur spells of involuntary unemployment.

Adjustments by Occupation and Industry

Below are several tables providing frequencies on the incidence of various adjustments. The figures presented in these tables are based on the National Science Foundation's (NSF) Longitudinal Survey of Scientists and Engineers (NLSSE). There is no attempt here to tie these adjustments to technological change. (See ref. 7 for a more in-depth description and analysis of these adjustments.)

Table C-1 provides observations on the frequency of investments in postschool education and OJT by S/Es. Occupational classifications are based on the respondent's self-concept.

Roughly 6 percent of the scientists and 4 percent of the engineers made formal educational investments in the same field, whereas about 10 percent of both samples invested in other fields. Considerably more investments were made in OJT and in course work provided at the employer's training school: 19 percent of the scientists and 18 percent of the engineers invested in OJT and 16 percent of the scientists and 20 percent of the engineers took courses at the employer's training facility.

Table C-2 provides figures on the percent of S/Es undertaking OJT by selected manufacturing industry. The incidence of formal OJT ranges from a low of 15 percent of the S/E work force in the fabricated metals industry to a high of 36 percent in the electronic computer industry. The incidence of reported informal OJT ranges from a low of approximately 16 percent in the aircraft industry to a high of 36 percent in the electronics computer industry.

Table C-3 provides observations on the frequencies of voluntary and involuntary turnover by S/Es over the 1969-72 period. Quit frequencies indicate that agricultural scientists were the least likely to quit during this period (7 percent) and that physicists had the highest quit percentage (15 percent). Among engineers, aeronautical/astronautical engineers had the highest frequency (5 percent) and agricultural scientists had the lowest frequency (0.4 percent). Among engineers, aeronautical/astronautical engineers had the highest permanent layoff incidence (8 percent) and mining/

Table C-1.—Frequencies of Postschool Education and On-the-Job Training by Scientific and Engineering Occupation, 1972-74

Occupation	Postschool education		On-the-job training	
	Same field	Other field	Formal	Informal
Scientists:				
Agricultural	0.035	0.055	0.242	0.315
Biological	0.048	0.123	0.055	0.141
Chemist	0.064	0.070	0.130	0.158
Earth/marine	0.052	0.054	0.212	0.196
Physicist	0.088	0.075	0.076	0.087
Engineers:				
Aeronautical/astronautical	0.052	0.133	0.217	0.156
Agricultural	0.055	0.055	0.273	0.164
Chemical	0.049	0.090	0.184	0.210
Civil/architectural	0.043	0.084	0.153	0.186
Electrical/electronic	0.063	0.106	0.240	0.176
Industrial	0.012	0.129	0.226	0.219
Mechanical	0.032	0.095	0.189	0.163
Metallurgical/materials	0.041	0.090	0.178	0.134
Mining/petroleum	0.023	0.062	0.229	0.209

Table C-2.—Formal and Informal On-the-Job Training Frequencies by Selected Major Industries, 1972-73 (working full-time year round in same job)

Industry	Percent of formal OJT	Percent of informal OJT
Aircraft[a]	25.4%	15.5%
Chemicals[b]	22.2	23.6
Electrical machinery[c]	30.1	19.7
Electronic apparatus[d]	28.0	17.6
Electronic computers[e]	46.3	35.5
Fabricated metals[f]	15.3	17.3
Machinery (except electrical)[g]	18.6	17.4
Motor vehicles[h]	31.2	21.8
Ordinance[i]	31.2	19.3

[a] Aircraft, aircraft engines, and parts

[b] Chemicals and allied products

[c] Electrical machinery, equipment and supplies for the generation, storage, transformation, transmission, and utilization of electrical energy

[d] Electronic apparatus, radio, television, and communication equipment and parts

[e] Electronic computers, accounting, calculating and office machinery and equipment

[f] Fabricated metal products (except ordnance, machinery and transportation equipment.

[g] Machinery (except electrical) including engines and turbines, farming and construction machinery, mining, metalworking, and other manufacturing and service industry machines

[h] Motor vehicles and motor vehicle equipment including trucks, buses, automobiles, railroad engines and cars.

[i] Ordnance, including manufacture of arms, ammunition, tanks, and complete guided missiles, space vehicles and equipment

Table C-3.—Frequencies by Voluntary and Involuntary Mobility by Scientific and Engineering Occupations, 1969-72

Occupation	Percent quit	Percent laidoff
Scientists:		
Agricultural	0.068%	0.004%
Biological	0.124	0.018
Chemist	0.095	0.042
Earth/marine	0.122	0.034
Physicist	0.147	0.053
Engineers:		
Aeronautical/astronautical	0.075	0.081
Chemical	0.093	0.049
Civil/architectural	0.179	0.034
Electrical/electronic	0.143	0.074
Industrial	0.157	0.066
Mechanical	0.130	0.068
Metallurgical/materials	0.083	0.057
Mining/petroleum	0.158	0.022

petroleum engineers had the lowest incidence (2 percent).

Table C-4 reports the percentage of engineers changing occupations during the 1969-72 period. Within the selected sample, 3.6 percent of engineers changed occupations, and about 54 percent of them shifted into other engineering occupations. The greatest exodus was out of aeronautical/astronautical engineering (6.7 percent) and the greatest entrance was into mechanical engineering (9.6 percent of those changing occupations). Of all occupation leavers, 73 percent moved into what appears to be equivalent engineering or scientific occupations. Another 6 percent shifted downward to technician jobs, and the remainder shifted into a wide mix of occupations ranging from secondary teachers to laborers.

An examination of the incidence of various labor market adjustments indicates that OJT (both formal and informal) is more widely experienced across S/E occupations than any other type of market adjustment. Although to some degree I am comparing apples to oranges, the above figures are consistent with the no-

Table C-4.—Frequencies of Occupational Char by Engineering Occupation, 1969-72

Occupation	Percent changed occupations
Aeronautical/astronautical	0.067%
Chemical	0.027
Civil/architectural	0.018
Electrical/electronic	0.039
Industrial	0.052
Mechanical	0.032
Metallurgical/materials	0.036
Mining/petroleum	0.015

tion that OJT plays a predominate role in adjusting to technological change.

The Case of the Computer Industry

The following section is a brief summary of my recent analysis of human capital adjustments by S/Es in computer manufacturing (9). The summary begins with a cursory overview of the structure and growth of the computer industry in the United States. Subsequently, I present some empirical evidence on the relationship between technological change and OJT.

TECHNOLOGICAL CHANGE IN THE COMPUTER INDUSTRY

Soma describes the computer industry structure as it has evolved from the early 1950's. During the 1950's there were three distinct segments: the electrical component manufacturers, the computer manufacturers (mainframe assemblers, sales, and maintenance), and the end users. By the 1970's this structure became much more complex. For example, some mainframe assemblers integrated vertically into electronic component manufacturing, and independent leasing and maintenance firms were established along with software firms, computer utilities, a used computer market, and peripheral manufacturers. A study of the computer industry, therefore, requires the examination of electrical component manufacturers, the various types of hardware manufacturers, and software firms. Of course the users of computer technologies include nearly every type of enterprise.

Technological change (as defined for present purposes) primarily has been contingent on major improvements in electrical components. The transition from vacuum tube technology (used in the early 1950's) to transistor-based product lines marked a substantial advance in computer technology. This adoption in electrical components appears to have underpinned the second generation of computers—from 1959 to 1964. The third generation of computers was founded on the development of integrated circuits which became economically competitive in the mid-1960's. If a fourth generation exists, it is not as well defined as the previous generations. "Most companies have introduced new lines of equipment with improved technology since 1965, but there is no single technical advance to be used in specifying a new generation. In terms of circuits, the primary change has been a movement from integrated circuits to large scale integration . . . " (5).

Based on these technologies, technological changes in computer hardware have varied widely and grown substantially. Phister plots annually many of these changes over the 1955-75 period. For example, he shows that the average internal memory bytes per general practice system remained roughly constant from 1955 to 1965 but steadily increased from 1965 to 1974. Other types of measurable innovations include increases in the: storage density of magnetic-core memories and moving-head files, off-line storage capacity of magnetic tape and disk pack media, average number of moving-head files, magnetic tape drives, and terminals per system (among many others).

EMPIRICAL ANALYSIS

Exploratory interviews with personnel managers of a convenient sample of firms in the computer and electronics industry yielded two important general observations. First, formal OJT plays the predominate role in human capital adjustments for employed S/Es. Formal OJT typically takes the form of training sessions ranging in duration from 2 to 3 days to 2 to 3 months, sometimes on an intensive full-time schedule but usually on a less intensive part-time schedule. The second major observation from the open-ended interviews is that employers decide who, when, and how much training is required to meet planned production and service goals. According to the sample of personnel managers, employees who survive the industry take the training as required—"its just part of the job."

It is hypothesized that rapid technological advancement in the computer industry requires considerable OJT to keep abreast of rapid obsolescence in human capital. The probability of OJT in any given year, therefore, is a direct function of technological change. As a general index of technological change, the change in the rate that new computers (including minicomputers) are introduced annually is employed in the probability model below. By using an index of the change in the rate of technological advancement, I am arguing that employers respond to noticeable shifts in deciding to provide OJT. The larger the shift upward in the introduction of new technology, the larger the probability that OJT is provided. Conversely, the larger the shift downward, the larger the reduction in OJT requirements.

Annual observations on S/Es in the computer industry are drawn from the NLSSE. Observations are pooled for the 1972-75 period for which the incidence of formal OJT is reported in the survey.

Restricting the sample to S/Es working full-time year round for the entire 1972-75 period, let $P\ (OJT)_{ij}$ be the probability of receiving formal OJT in year i by individual j. The cumulative logistic function:

$$P\ (OJT)_{ij} = 1/1 + e^{-}\ (B_{ij}\ X + U_{ij})$$

is estimated by maximum likelihood. $P\ (OJT)_{ij} = 1$, if OJT was made in year i by individual j, 0 otherwise; U_{ij} is the error term, and

$$\begin{aligned} B_{ij}\ X = {} & B_{0ij} + B_{1ij}\ (NMODELS) + B_{2ij}\ (CTOTREV) \\ & + B_{3ij}\ (AGE) + B_{4ij}\ (BS) + B_{5ij}\ (MS) + B_{6ij}\ (PHD) + \\ & B_{7ij}\ (OCCUP) + B_{8ij}\ (TENURE) \end{aligned}$$

where:

NMODELS = rate of change in number of new computer models introduced in year i-3
CROTREV = percentage change in annual total industry revenue in year i-1
AGE = age in year i for individual j
BS = 1 if had bachelors degree in year i for individual j
MS = 1 if had masters degree in year i for individual j
PHD = 1 if had Ph.D. in year i for individual j
OCCUP = zero-one dummy variables for engineers, computer specialists, and managers (scientists and others in benchmark)
TENURE = years employed in job in year i for individual j

Once a new innovation is introduced to the market, there is a delay before it becomes widely adopted. Thus, obsolescence and the need for retraining becomes a function of that adoption delay. Knowing the appropriate lag of the change in the rate of introduction of new computers is problematic. Unfortunately there is little empirical evidence about the rate of diffusion of other technological advancements on which to base a judgment. Work by Mansfield, et al. (13), however shows that the introduction of numerically controlled machine tools has taken anywhere from 6 to 15 years to become widely adopted by major user industries. Since technological advancement in the computer industry has been particularly rapid, one would infer that the lag is considerably shorter in the computer industry than in other industries. In order to estimate the most "appropriate looking" lag, the model is tested against 1- to 5-year lags on the NMODELS variable.

RESULTS

The results of the estimated probability model are reported in table C-5. The partial derivatives of $P\ (PJT)_{ij}$ with respect to each variable are given, evaluated at the mean P (OJT) (= 0.386). Using a 3-year lag on the rate of change in the number of new models introduced annually (NMODELS), a significant positive relationship with the probability of OJT is found. The increased probability in OJT in 1972 (where the rate of change between 1968 and 1971 = −25), is estimated to be as much as 15 percentage points. Given that the mean probability of investing during the 4-year period under consideration (1972 to 1975) is 0.39, the impact of technological change is apparently considerable.

Table C-5.—Estimation of the On-the-Job Training Probability Model, 1972-75

Variable	Mean	Coefficient[a]	t-value
NMODELS	−2.75	0.004	1.811
CTOTREV	6.50	−0.007	−0.979
AGE	39.25	−0.015	−3.555
BS	0.59	0.157	1.291
MS	0.30	0.128	0.996
PHD	0.03	0.667	3.226
Computer specialist	0.35	0.266	3.965
Manager	0.12	0.179	1.951
Other	0.04	0.442	2.810
TENURE	6.63	0.010	1.333
Intercept		0.173	0.885
Chi square	45.55 (1 [illegible])		
N	324.00		

[a] The coefficients reported above are $\beta\ (\bar{P})(1 - \bar{P})$, where β is the logit estimate and $\bar{P}$ is the mean probability of on-the-job training (= 0.386).

No significant relationship is found between the percentage change in total revenue and the probability of OJT. This holds regardless of the lag employed.

Age shows the expected negative relationship, where the partial derivative is −0.015 per year of age; significant at the 0.01 level. As a point estimate, this indicates that a 40 year old S/E would be less likely to receive OJT than an identical 30 year old by as much as 15 percentage points. Further tests to examine the linearity of the relationship (i.e., using age in log and quadratic forms) support the inference that the training-age profile is downwardly linear.

Only for Ph.D.s does the probability of OJT differ by level of education. But here the estimate is peculiarly large, albeit, highly significant. Given the size of the estimate (0.667) and the fact that only 0.03 of the sample are Ph.D.s, I find it difficult to place much faith in the estimate. On the other hand, the results suggests that Ph.D.s are especially prone to receiving formal OJT—perhaps because their functions are so closely tied to generating technological change.

The set of occupational dummy variables shows that there are substantial differences among occupations. Since any occupational classification must be compared to all others (i.e., all others, including engineers, are in the benchmark), it is impossible to estimate the differences between any two occupations. Yet it can be inferred that computer specialists and managers retrain more frequently than engineers.

Finally, TENURE obtains an unexpected positive sign but it is insignificant at conventional levels of confidence. The positive sign does suggest, however, that OJT is more likely received later than earlier in one's tenure.

CONCLUSIONS

Using a pooled cross-section time series logit probability model, it was found that technological change has a substantial impact on the probability of receiving OJT during any given year. The results are limited, however, and must be treated as first approximations. First, the time period under study is limited to 1972 to 1975 because of data limitations—both with respect to individual data and available indices of technological change. Second, the pooling technique suffers from a potential violation of the assumption of independence. That is, if an important variable correlated with the dependent variable is omitted at the cross-section, pooling that omitted variable (in effect) over time results in autocorrelated error. Although the estimates would be unbiased, the standard errors would be understated.

As a first approximation, (and bearing in mind the above limitations) the results support the consensus of a sample of personnel managers in the computer industry that formal OJT plays in a crucial role in adapting the S/E labor force to changing production functions. Furthermore, the model estimates that the lag between the introduction of new computer models and subsequent training is approximately 3 years on average.

A similar empirical analysis of the linkage between postschool educational investments and technological change yielded no significant relationship. Because technological change in the computer industry is so rapid and universities cannot afford to provide training based on expensive technologies, continuing education programs do not provide a viable alternative of adjustment to technological change—at least for S/Es in the computer industry.

Programmable Automation and Labor Saving Adjustments

What Can We Expect?

The above analysis of OJT indicates that the acquisition of new skills and knowledge is widespread for the S/E labor force. My impression is that the professional S/E labor force is probably the most highly adaptable segment of our labor force. By the very nature of S/E educational training, workers are well equipped to make adjustments to outdated skills and knowledge. Indeed one of the primary roles of the S/E labor force is to advance our knowledge and pursue the goal of technological and innovative improvements.

Consequently, growth in programmable automation in manufacturing is unlikely to cause considerable disruption for the experienced S/E labor force. Adaptation to technological and innovative advance caused by programmable automation will come in the form of formal and informal OJT. The more rapid the developments in programmable automation, the greater will be the extent of OJT and the less likely formal education will play an important role in providing experienced S/Es with new skills and knowledge. This latter conclusion is based on what has been observed in the computer industry. Universities in general simply do not have the resources for accumulating and developing the necessary physical capital to train S/Es in the latest technologies. Because of limited resources, research and development (R&D) in programmable automation unfortunately will greatly limit universities from providing students with advanced training, which in turn will slow the reindustrialization of U.S. manufacturing.

Therefore, the potential fly in the ointment is the lack of resources available to universities to play lead roles in R&D and the education of new S/Es. The problem is that newly trained S/E graduates will not provide the manufacturing industry with cutting-edge talent. Instead, the industry will need to provide substantial training to new S/E entrants. Consequently, instead of recruiting S/Es with skills capable of satisfying immediate technical needs, manufacturing firms will experience a lag in recruiting S/Es to implement and improve new programmable automation operating objectives.

To aggravate the problem, private industry appears to be recruiting some of the best talent in S/E Ph.D.s; not only newly minted Ph.D.s but also experienced educators. The heart of this problem lies in the substantial differences between current salaries of Ph.D.s in universities vis a vis private enterprise. This brain drain from the universities implies that opportunities for more widespread and advanced educational training will be retarded.

The above scenario suggests that although programmable automation will be ready technically for diffusion throughout manufacturing, the S/E labor market will not have the requisite skills to implement the technology—at least in the short run. This will hamper diffusion of programmable automation and any immediate expected improvements in productivity attributable to programmable automation.

Research Needs

If my best guess about what to expect is reasonably accurate, then appropriate social policy should focus on providing universities with the necessary resources to establish educational curricula in programmable automation. Additional resources can come from government and/or private industry. The primary research need is to examine the current and planned R&D and educational activities of higher education. The basic questions to investigate are:

1. What programs focusing on programmable automation have been established? We know, for example, that several major universities have established research centers in programmable automation; including Stanford, Purdue, Carnegie-Mellon, Massachusetts Institute of Technology, and the University of New Hampshire (among others).
2. Where have universities received resources for these programs? The above-mentioned universities have relied primarily on NSF grants, donations from corporations, and university budgets.
3. Are universities gearing up for R&D and educational programs in programmable automation?
4. What resource limitations are the universities facing?
5. To what extent is private industry attracting top Ph.D. talent? Is this recruitment causing shortrun bottlenecks in developing programmable automation curricula and R&D activities? How can universities maintain their S/E faculty in light of low relative salaries?

Answers to these questions are important not only to government policymakers but also to higher education administrators and manufacturing executives. Thus, I would recommend that OTA investigate the answers to the above set of questions. A survey of major educational institutions could provide OTA with reliable information to evaluate the above scenario. If such an assessment warrants considerable interest by the U.S. Government, then a task force composed of administrators from higher education, executives from manufacturing, and officials from government should be established. The purpose of the task force would be to design and coordinate educational efforts to train future S/Es in programmable automation.

In the next section I briefly overview several data collection efforts by NSF (Division of Science Resources Studies). Ongoing efforts by NSF in collecting and analyzing data about S/E labor markets are extensive and in depth. They are potentially very suitable for collecting the type of information I have suggested above. Although I am not recommending at this point any additional research, data collection efforts by NSF also provide the most useful data source for monitoring how well the S/E labor force adjusts during an era of programmable automation—both in terms of new entrants and experienced S/Es.

National Science Foundation Data Bases (see NSF)

SURVEY OF SCIENTIFIC AND ENGINEERING EXPENDITURES AT UNIVERSITIES AND COLLEGES

This survey is conducted biennially to provide information on three areas of academic spending for scientific activities: 1) R&D budgets, 2) expenditures for departmental research and instruction, and 3) capital expenditures.

SPECIAL SURVEYS

NSF also conducts special surveys. Prominent among these is the *Higher Education Panel Survey* which is conducted by the American Council of Education. The survey is conducted several times a year with the primary objective of providing quick responses to current policy questions relevant to S/E labor markets. (This survey may be especially well suited for the type of quick evaluation suggested in "Research Needs" above.)

A second example is the survey of *Scientific Equipment in Academic Institutions*. Its purpose is to measure the adequacy and utility of available equipment.

SURVEY OF SCIENTIFIC AND ENGINEERING PERSONNEL EMPLOYED AT UNIVERSITIES AND COLLEGES

This survey collects data about academic S/Es by field of employment and primary function.

SURVEY OF GRADUATE SCIENCE STUDENTS AND POST-DOCTORALS

The objective of this survey is to obtain data on the characteristics of graduate science and engineering enrollment at the departmental level. Data from this survey provide a base for assessing the relationship between financial support and shifts in graduate enrollments.

THE NATIONAL LONGITUDINAL SURVEY OF SCIENTISTS AND ENGINEERS

This biennial survey is a continuing longitudinal effort to maintain a comprehensive picture of the development and utilization of individuals who were part of the S/E labor force in 1969. The survey elicits information about human capital investments, earnings, and employment/reemployment experiences.

THE NATIONAL SURVEY OF RECENT SCIENCE AND ENGINEERING GRADUATES

This survey is conducted biennially, furnishing information on graduates in science and engineering fields; including data on employment, earnings, and other labor market experiences.

THE NATIONAL SURVEY OF DOCTORATE RECIPIENTS

This is a biennial survey with the primary objective of estimating the national supply and utilization of doctoral S/Es.

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TECHNOLOGY AND LABOR

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Technology changes the way goods and services are produced and distributed—and for all its potential benefits, including creation of new jobs, technology also has destructive effects on workers and their jobs. Therefore, workers and their unions have a direct and vital interest in how technology is introduced in the workplace—to make sure people get priority over technology, to make human values prevail.

Technology often involves labor-saving operations—increased production with the same number or fewer workers. This may wipe out many existing jobs. It may raise new dangers to workers' safety and health. Of course, new jobs may also be created. New protections may be achieved for workers' safety and health. But the impact of new technology is often to eliminate some jobs, change the job content of others, change skill requirements, and change the flow of work.

Technology often causes changes in industry location—shutdowns of departments and entire plants and shifts to new locations in suburban or outlying areas and sometimes overseas. No industry is immune to such changes, which are constantly shifting the structure of skills, occupations, jobs, and earnings of American workers.

Collective Bargaining

Collective bargaining holds a vitally important role in meeting the challenges, opportunities, and dangers of new technology. There is much to be learned from past experience in collective bargaining. The flexibility of this institution, the American system of labor-management bargaining at the plant, company, and industry level, helps workers negotiate and settle with employers on reasonable and humane protections for workers against the potentially adverse effects of job-destroying technological innovation. Mature collective bargaining relationships between labor and management provide more opportunities and a sound basis for special labor-management committees to deal with adjustment to technological change within the framework of collective bargaining.

Collective bargaining can help democratize labor-management relations and humanize the workplace and work itself, including the impact of new technology on workers' jobs and earnings. Collective bargaining can provide cushions to soften the adverse impact on workers by setting up adjustment procedures and programs at the workplace. In a full employment economy—linked with adequate employment services, employment and training programs, and unemployment compensation—the disruption of workers' lives and the job displacement resulting from technological change can be minimized.

Historically, unions have responded in a number of ways to the introduction of new technology. In 1960, Sumner Slichter, James J. Healy, and Robert Livernash, reported that major determinants of union policies toward technological change are:[1]

1. the nature of the union, meaning specifically whether it is a craft or industrial union;
2. the economic condition of the industry or the enterprise, or occupation, whether it is expanding or contracting, whether the industry is highly competitive or not;
3. the nature of the technological change, the effect on jobs and on the bargaining unit, the effect on workers' skills and job responsibilities; and
4. the stage of development of the technological change and the stage of development of union policy toward the technological change.

Slichter, Healy, and Livernash distinguish five principal policies that unions adopt when faced with technological change: 1) willing acceptance, 2) opposition, 3) competition, 4) encouragement, and 5) adjustment with an effort to control use of the new technology. They note:

> The most usual policy of unions toward technological change is willing acceptance. This happens in the numerous cases in which the technological change makes little difference in the kind and degree of skill required and has little immediate effect on the number of jobs. But the gain in productivity from the change may make it attractive by giving labor improved opportunity to bargain for wage increases. Unions may be led by favorable bargaining opportunities to accept willingly technological changes that involve a mixture of advantages and disadvantages. Thus, the bargaining advantages that accompany a change requiring greater skill may lead to willing acceptance even though it greatly reduces the number of jobs.

Slichter, Healy, and Livernash go on to point out that no national union in recent years has destroyed itself by fighting technological change.

> Nor is there record of any union in recent years being able to prevent technological change by opposing it—though many unions have retarded recent changes temporarily and locally. Union wage policies appear to have been partly responsible for stimulating technological change under some circumstances and may have affected the distribution of gains. Three principal effects have been produced by union policies toward technological changes:
>
> (1) They have tended to give to the holders of jobs on the new machines or new processes somewhat higher wages relative to other workers in the same plant—in other words, they have tended to introduce distortions in the wage structure of the plant.
>
> (2) They have tended to a slight extent to cause the new techniques to be operated with excessive crews and under make-work rules.
>
> (3) They have considerably eased the hardship of displacement, partly by forcing managements to do advance planning in the introduction of technological changes and partly by giving displaced workmen an opportunity to qualify for other jobs.

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[1] Sumner Slichter, James J. Healy, and Robert Livernash, *The Impact of Collective Bargaining on Management* (Washington, D.C.: The Brookings Institution, 1960), ch. 12, "Union Policies Toward Technological Change."

Using the approach developed by Slichter, Healy, and Livernash to distinguish the five principal attitudes that unions take toward technological change, Doris McLaughlin of the University of Michigan made a survey of union officials, management, and mediators and arbitrators on the impact of labor unions on the rate and direction of technological innovation.

The McLaughlin report[2] found that willing acceptance was the most common response American labor unions make to the introduction of new technology. The next most common response was initial opposition, but this was followed by adjustment, so that, in the long run, willing acceptance or adjustment were, by far, most common.

A negative union response to the introduction of technological change was invariably the result of belief that acceptance would have an adverse effect on a large or important segment of the union's membership. If the employer convinced the union's leaders that their members would not be adversely affected, or that those who were adversely affected would receive some off-setting benefit, union opposition disappeared.

The three most important variables in determining union reactions, in order of importance, were:

1. the state of the economy,
2. union leaders' perception of the inevitability or necessity for the change, and
3. the nature of the industry.

McLaughlin noted that, depending on union perception of these three variables, a fourth variable—where decisionmaking power lay—became crucial. If the international union held the decisionmaking power, a decision on how to react to the new technology would be made only on consideration of the first three variables. However, if decisionmaking power lay with local union leaders, three more variables became relevant:

4. how local union leaders perceive the impact of the new technology on the bargaining unit,
5. how local union leaders perceive the "quid pro quo" offered by the employer to the affected union members, and
6. how local union leaders perceive the impact on those union members left in the unit after the new technology is introduced.

Third-party action by mediators, arbitrators, or judges did not seem to affect the outcome, according to the report, but did appear to affect the process by which unions and management reached accommodation to the effects of the new technology. These third-party agents, as outsiders, serve a useful function in taking the heat off local union leaders "when otherwise politically delicate decisions need to be made with regard to the introduction of new technology," the report states.

Surprisingly, labor unions are not the major stumbling block to new technology and higher productivity, McLaughlin concludes, but "employer representatives, particularly at the middle management level, were often cited as constituting the real barrier to the introduction and effective use of technological innovation."

In 1964, the Bureau of Labor Statistics reported[3] that some of the major labor-management efforts to protect against the effects of new technology have included:

1. guarantees against job or income loss and, in some cases, against loss of supplementary benefits for varying periods,
2. compensation for employees who lose their jobs,
3. guaranteed income for workers required to take lower paying jobs,
4. provisions for retraining,
5. provisions for transfer to other plants and payment of relocation expenses, and
6. agreements to provide workers with notice of plant closings or other major changes.

Some agreements have established joint labor-management committees to recommend methods of providing for workers affected by automation. The report concluded that:

> These arrangements typically are combined with provisions for retention of workers with greatest seniority, but in a limited number of cases, efforts are made to spread work among larger numbers of employees or to encourage early retirement of workers with relatively high seniority.

In 1966, the Automation Commission[4] called attention to the need for private sector efforts to facilitate adjustment to technological change including reliance on attrition, an advance notice early warning system, job counseling and job-finding assistance, training and retraining. The Commission noted the rationality of using the seniority principle in the case of layoffs and the seriousness of the need for pension and health benefits to continue during periods of unemployment. They also pointed out that technological improvements can bring more flexibility to work schedules and more leisure to employees through reduced hours of work per day, per week and per year.

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[2] Doris B. McLaughlin, *The Impact of Unions on the Rate and Direction of Technological Innovation* (Detroit, Mich.: Institute of Labor and Industrial Relations, University of Michigan—Wayne State University, February 1979), report to the National Science Foundation, grant PRA 77-15268.

[3] *Collective Bargaining and Technological Change* (Washington, D.C.: U.S. Department of Labor, Bureau of Labor Statistics, March 1964), BLS report No. 266.

[4] *Technology and the American Economy*, vol. 1 (Washington, D.C.: National Commission on Technology, Automation, and Economic Progress, February 1966).

The record of collective bargaining response to technological change offers many examples of both success and failure, the Commission noted:

> Collective bargaining has proved to be an excellent vehicle for the effective management to change; it permits those directly affected by the change to deal with it firsthand and with a familiarity that takes into account peculiarities and problems peculiar to an enterprise. Especially in recent years, some managements and unions, occasionally but not usually with the help of outsiders, have developed, with varying degrees of ingenuity and success, plans to facilitate change."

But the Commission warned:

> Despite its many successes, collective bargaining has often failed, and sometimes has failed spectacularly, to deal effectively or even responsibly with the management of change. It has been argued, not unreasonably, that the failures are the fault of the parties, not of the system.
>
> Procedurally, the process of collective bargaining on basic issues has tended to stagnate during the life of the agreement and to accelerate frantically in an atmosphere of crisis immediately preceding contract renewal. Happily, employers and unions in a number of industries are abandoning this pattern in favor of more or less continuous discussion. Basic issues such as adjustment to technological change cannot be resolved, however, by a small team of negotiators working themselves into a state of physical and mental exhaustion for a few months every 2 or 3 years. These issues must be dealt with patiently, carefully, and above all, continuously, until satisfactory solutions emerge. This kind of bargaining calls for ability of the highest caliber on the part of leaders of both labor and management.

In the 15 years since the Automation Commission's report, with generally slow economic growth and recessions in 1969-70, 1973-75, 1980, and 1981-82, economic conditions have not been conducive to easy adjustments to technological change. The impact of new technology has become much more pervasive in the 1980's than it was in the 1960's.

It must be emphasized that it is easier to deal with adverse effects of technological change in a general economic climate of full employment. National economic policies must aim at full employment for a variety of economic, social, and moral reasons. Among those reasons we must recognize the need to facilitate successful and humane adjustments to job-destroying technology in both the private and public sectors.

Much progress has already been achieved through collective bargaining. For example, a 1981 Bureau of Labor Statistics study,[5] updating a similar 1966-67 study, presents a wide range of contract language and statistical summaries of contract language on plant movement, plant transfer, and relocation allowances, many of which relate to the effects of technological change. Agreements limiting plant movement rose from 22 percent in the 1966-67 survey to 36 percent in the 1980-81 survey of some 1,600 contracts, while worker coverage rose from 38 to 49 percent. Interplant transfer provisions increased from 32 to 35 percent and worker coverage went from 46 to 49 percent. Agreements dealing with relocation allowances increased from 34 to 41 percent while worker coverage went up from 60 to 65 percent.

On the issues of the major technological change, work transfer, or plant closings, some major contracts have a variety of provisions.[6] For example, the United Auto Workers (UAW)-General Motors contract provides for advance notice to the union in cases of technology-related permanent layoffs, and negotiation of rights related to plant closing, department closing, and company transfer of work. Workers have the right to training for a new job in cases of technology-related permanent layoff. In the case of plant closings, department closings and transfer of work, workers have the right to bump to another job in the same plant, transfer to a replacement facility, or transfer to a new plant. They will receive preferential hiring at another plant, keep seniority with respect to fringe benefits, get moving expenses up to $1,355, take layoff with recall rights, and get severance pay.

The United Steel Workers' contract with Kennecott Copper includes a no-layoff clause and attrition protection for workers affected by technology changes which will permanently eliminate their jobs. Under this contract, workers have the right to bump to another job in the same plant or in another plant. The Transit Workers' contract with the New York City transit system and the Newspaper Guild's contract with the New York Times also have no-layoff contract protection.

The Steel Workers' contract with American Can Co. calls for a 12-month advance notice of permanent layoffs related to technological change. The United Food and Commercial Workers' contract with Armour calls for 6-month notice, and the Guild-New York Times agreement calls for 4 months. There are contracts with advance notice requirements as short as 7 days and contracts with advance notice requirements, but no specified time period.

A broad range of labor-management cooperation is already included in many other labor-management agreements with negotiated specific procedures for adjusting to technological change.

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[5] U.S. Department of Labor, Bureau of Labor Statistics, *Major Collective Bargaining Agreements: Plant Movement, Interplant Transfer and Relocation Allowances,* Bulletin 1425-20, July 1981. The 1966-67 study was reported in U.S. Department of Labor, Bureau of Labor Statistics, *Major Collective Bargaining Agreements: Plant Movement, Transfer, and Relocation Allowances,* Bulletin 1425, July 1969.

[6] The following contract provisions are listed in Industrial Union Department, AFL-CIO, *Comparative Survey of Major Collective Bargaining Agreements, Manufacturing and Non-Manufacturing, March 1979,* December 1979.

One method to ease the human costs of new technology is to assure advance information to workers and their unions about management plans for future innovation which will affect workers with job loss or other serious problems. Major technology changes result from management decisions taken long before the new technology is actually introduced, often years earlier. Certainly there should be long advance notice before any technological change which results in layoffs or plant shutdown. The failure of management to institute worker safety-health and environmental protections should not be the way workers learn about intended plant shutdowns or major layoffs.

An "early warning system" of advance notice helps make it possible to ease the problems of affected workers. Such "early warning" provisions have long been standard in many union contracts. With advance notice and labor-management cooperation, workers can look for or train for a new job, perhaps with the same employer in the same plant or at another location. Employer-paid retraining is an important part of any adjustment-to-innovation program.

There are other methods and techniques for labor-management cooperation to cushion adverse effects from changing technology. These include income maintenance with work and/or pay guarantees. One way is through "no-layoff" attrition to reduce the work force by natural turnover, deaths, retirements, and voluntary quits, thus protecting the jobs and earnings of those workers who remain with the company. Of course, attrition alone is not an adequate solution. "Red circle" earnings protection for workers downgraded through no fault of their own attaches a wage rate to an individual instead of to the job itself and thus protects workers against loss of income which might result from innovation-induced downgrading.

Seniority is a key principle in protecting workers against layoffs and downgradings. This rewards long service, but does much more—properly reflecting the worker's investment in the job and the company's investment in the worker. Early retirement is an option that older workers should have available when major technological change wipes out their jobs. But the option should be available as a free choice, not as a requirement. Many older workers cannot afford to retire early and others prefer to continue working.

Transfer and relocation rights and mobility assistance to workers are other ways to provide job and income protection. Within-plant and interplant transfers, relocation assistance, severance pay, pension rights and seniority protections and supplemental unemployment benefits can all help cushion adverse effects on workers and their families when industrial innovation occurs.

Shorter workweeks and reduced time per year on the job, including longer paid vacations and sabbatical leaves, also can ease the negative employment effects of technology.

Electrical machinery manufacturing is an industry where extensive use of robots is expected in the future. The June 1982 General Electric agreement with the International Union of Electrical Workers includes these protections for workers who lose jobs to robots and automation:[7]

> A production employee whose job is directly eliminated by a transfer of work, the introduction of a robot or of an automated manufacturing machine and who is entitled to transfer or displace to another job shall basically retain the rate of the eliminated job for a period of up to 26 weeks.
>
> The company shall give the union advance notice of a minimum of six months of plant closing or transfer of work and of a minimum of 60 days of the installation of robots or automated manufacturing machine for production.
>
> An employee who is terminated because of a plant closing will be assisted to find new jobs and learn new skills under an employment assistance program which will include job counseling as well as job information services.
>
> An employee with two or more years of service who is terminated as a result of a plant closing will be entitled to receive education and retraining assistance, including reimbursement of $1,800 for authorized education expenses.

Obviously these provisions do not constitute total protection but they offer some protection and some help to displaced workers.

Public Policy

More information is needed on the effects of changing technology on workers. Federal action is needed to set up a clearinghouse to gather information on a continuing basis on innovation and technological change and its effects on the welfare of the American people, on jobs, skills, training needs, and industry location. Few economic studies of the impact of technological change exist because there is no systematic data-gathering relating to the changing technology of American production. With more and better information, public and private adjustment programs can better avoid needless human hardship and suffering which too often result from the disruptive impact of changing technology.

Through this clearinghouse, the Federal Government could provide unions and employers with comprehensive information and service, upon request, to help develop labor-management solutions for the complex problems related to the impact of technological change at the workplace.

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[7] Bureau of National Affairs, *Daily Labor Report*, June 29, 1982.

Technology-caused economic dislocation and other kinds of dislocation—including plant shutdowns caused by corporate merger mania and by recession, job loss from trade policies and production shifts away from defense-related industry—require cooperative labor-management efforts and also national programs to deal with these complex problems. Further exploration is needed of a variety of such programs, including proposals dealing with plant shutdowns and plant relocation and with reconversion of defense-related industry.

Occupational training and retraining may perhaps help displaced workers acquire new skills and new jobs—but such new jobs may be at lower skill levels and at lower pay. Furthermore, the loss of an industry and the skills and know-how that go with that industry diminish the essential diversity and pluralism required for a healthy economy and healthy society.

In mid-1982 Congress was moving to approve new federally supported job training legislation, but the scope of the program is too small to help the millions of workers who have lost their jobs to technological change and economy shifts. The recession has sharpened union pressures to get retraining commitments from employers.[8]

Workers who lose their jobs because of plant closings may not be able to find new ones or may be forced to work at reduced pay. Family life is often disrupted. The mental and physical health of displaced workers often declines at a rapid rate. Research over a 13-year period indicates that the suicide rate among workers displaced by plant closings is almost 30 times the national average.[9] Such workers also suffer a far higher than average incidence of heart disease, hypertension and other ailments.

Bills to deal with this grave economic and social problem have been introduced in Congress.[10] Although these bills differ in some respects, they would do much to counteract the devastating effects of shutdowns and relocations. Unfortunately, they do not address the problems caused by the relocation of governmental facilities. Among other things, these bills would:

1. require firms to provide advance notice of their intentions to close or relocate a major facility;
2. advocate programs to support troubled businesses, including incentives to promote employee ownership;
3. call for the issuance of economic impact statements and Federal investigation of the circumstance; and
4. require employers, whenever existing jobs cannot be saved, to provide minimal protections to their workers in such matters as transfer rights, relocation expenses, severance pay, pension protection, health care, and job training.

Three states—Wisconsin, Maine, and Michigan—have laws relating to plant shutdowns, and some 15 other States have proposals pending with State labor organizations pressing for action on protective plant shutdown legislation at the State level. However, because of "competitive laxity" among the States in their efforts to attract new business and "runaway" business, Federal legislation with national plant closings standards is essential.

Unfortunately, since reporting on plant closings is voluntary, the U.S. Government does not have centralized, comprehensive information on this important social and economic issue. We don't even know whether most plant closings are related to technology changes or tax incentives, to short- or to long-term economic pressures.

For labor it is crucially important to require employers to recognize their responsibilities to their employees and their communities before they shut down a plant and to provide economic protections to workers and their families who must suffer the consequence of too hasty corporate action. There is nothing radical or unusual about national legislation requiring advance notice and other worker-community protections. In other nations, private business firms—including affiliates and subsidiaries of many American firms—find they can live with laws requiring advance notice and other protections for workers and communities against the adverse effects of economic dislocation and plant shutdowns.

In terms of international comparisons, Sweden requires 6 months notice where more than 100 workers are involved, 4 months notice where 26 to 100 workers are involved, and 2 months notice where 5 to 25 workers are involved. Under Swedish law, no dismissals may take place until the unions have been contacted and granted an opportunity to negotiate concerning the issues and consequences of the dismissals. In the United Kingdom, 90-day notices must be given where 100 or more workers are involved and 30 days in plants employing 10 to 99 workers. Failure to communicate with the unions and to give the appropriate notice can make the employer liable for continuing pay of the workers during the required notice period. In France Greece, and the Netherlands, prior to making large-scale dismissals, the firm must have permission of the government to lay off the workers and in actual practice the advance notice period is as long as half a year to a year depending on the specific circumstances.

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[8] For example, see "Retraining Displaced Workers: Too Little, Too Late?" *Week*, July 19, 1982, pp. 178-185.

[9] Barry Bluestone and Bennett Harrison, *Capital and Communities: The Causes and Consequences of Private Disinvestment* (Washington, D.C.: Progressive Alliance, 1980), pp. 78-82. The health-unemployment link is one of the most clearly documented social research conclusions, e.g., Harvey Brenner, *Estimating the Costs of National Economic Policy Implications for Mental and Physical Health, and Criminal Aggression*, Joint Economic Committee, U.S. Congress, Oct. 26, 1976.

[10] For example, see 96th Cong. bills H.R. 5040, introduced by Congressman Ford of Michigan; S. 1608, introduced by Senator Riegle of Michigan; S. 1609, introduced by Senator Williams of New Jersey; and S. 2400, introduced by Senator Metzenbaum of Ohio.

These examples indicate that advance notice is a practice with which firms can live. It must also be remembered that in most foreign countries the benefits paid workers are generally two-thirds of lost earnings for up to 1 year after the layoff.

Unfortunately, in the United States, there are a number of tax advantages provided for corporations which close down even viable, moneymaking plants. Congress should look into these plant closings very carefully to determine if there is indeed an array of tax incentives encouraging businesses to close down plants. Legislation must be created which will stop such incentives and will prevent tax-related plant shutdowns. Legislation must also be created which will establish basic job and income protections for workers and protection of workers' pension and health care and other benefits, to deal in an effective and humane way with the economic and social dislocation resulting from plant closings.

Industrial Democracy

The potential for misusing technology is great, but the possibility of human progress through the wise and humane use of technology is equally great. The opportunity for new technology to be introduced with minimal social disruption will be greatly enhanced if workers and employers have an equal opportunity for discussion and joint decisionmaking on the subjects of changing technology and the quality of working life.

Collective bargaining, an established institution in our democratic society, has been a fair and workable process for joint labor-management decisions on wages, working conditions, and other major issues. It is therefore a logical mechanism for increasing the involvement of workers in such areas of decisionmaking as adjustment to new technology.

New technology and rising expectations are forcing transformations in the workplace. Applications of new technology should be humane for workers as well as profitable to business. Human and social values must be more highly valued in the production process, not only when the process is producing goods and services, but also when it is producing cultural and social values and leisure and unemployment. The human desire for greater autonomy and greater participation in decisionmaking on the shop floor, in the corporate boardroom, and in national economic policymaking must receive higher priority. Improvements in the "quality of work life" (QWL) include a broad range of issues, such as better occupational safety and health, as well as work-organization, work environment, and longrun investment, employment and training decisions, and the introduction of new technology. These QWL issues are logical subjects for joint labor-management negotiation and decision. But employers must not use QWL as a disguise for union-busting.

Irving Bluestone, a former UAW vice president, has been a strong proponent of increased worker participation in corporate decisions. He warns:[11]

> The joint union-management programs that are in existence have not yet proven themselves in any permanent sense. They must be subject constantly to review and change as management, the union, and the workers learn by doing. Although it is not possible to set forth a precise blueprint to ensure the successful participation of workers in the decision-making process, experience already indicates certain criteria that are basic:
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> - The programs should be voluntary. Workers must have the free opportunity to decide whether or not to participate in the program. To order compulsion is to invite resistance and failure.
> - Workers should be assured that their participation in decision-making will not erode their job security or that of their fellow workers, that they will not be subject to 'speed up' by reason of it, and that the program will not violate their rights under the collective bargaining agreement.
> - Workers should genuinely experience that they are not simply adjuncts to the tool, but that they are bent toward being creative, innovative, and inventive plays a significant role in the production (or service) process.
> - Job functions should be engineered to fit the worker; the current system is designed to make the worker fit the job on the theory that this is a more efficient production system and that, in any event, economic gain is the worker's only reason for working. This theory is wrong on both counts.
> - The worker should be assured the widest possible latitude of self-management, responsibility, and opportunity for use of "brainpower." Gimmickry and manipulation of the worker must not be employed.
> - The changes in job content and the added responsibility and involvement in decisionmaking should be accompanied by an effective reward system.
> - Workers should be able to foresee opportunities for growth in their work, and for promotion.
> - The role of workers in the business should enable them to relate to the products being produced or the services being rendered, and to their meaning in society; in a broader sense, it should also enable them to relate constructively to their role in society.

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[11] Irving Bluestone, ch. 12, "Emerging Trends in Collective Bargaining," in *Work in America: The Decade Ahead*, Clark Kerr and Jerome M. Rosow (ed.) (New York: 1979), Van Nostrand Reinhold, pp. 249-50.

Quality of Work Life

The conflict theory of labor relations is the soundest basis for worker representation, worker participation, and worker gains. Conflict is institutionalized in our political system. Conflict is institutionalized in our legal system. Conflict is institutionalized in our economic system. And we have institutionalized conflict in labor-management relations through the American system of collective bargaining.

But the adversary role, which is appropriate to the conflict of collective bargaining, should be limited to the period of negotiation—and during the life of the contract, the adversary relationship can very logically and appropriately be replaced by cooperation aimed at maximizing the potential success of the enterprise, the company, or the establishment. The labor relations cycle should be one of periods of conflict during the negotiating period followed by the longer contract period of cooperation.

Collective bargaining is basic and fundamental to honest labor-management cooperation—and such cooperation can be mutual self-help supplement to collective bargaining. Committees that exist outside collective bargaining or try to take over the process of collective bargaining are not to be trusted.

Labor unions today jointly participate with management in thousands of safety committees, apprenticeship committees, communitywide labor-management committees, quality of work life committees, quality circles and other joint labor-management efforts. As a result, labor-management committees are joining together to deal with matters of mutual interest such as foreign trade; Federal, State, and local programs; community philanthropic purposes; and revitalization and strengthening of their industry and their community as well as those committees which give workers a direct voice in the issues of the workplace, including investment and innovation with new technology.

But, only the collective bargaining stature of their unions establishes workers as real partners in those labor-management committees. Any action that weakens a union, distorts the balance in its relationship to management, or its ability to represent its membership, will damage that union's ability and desire to participate in committees of any kind with a particular management.

Any program which strengthens the union's ability to grapple with the new issues union members want addressed, including technology change issues, any program which holds out real promise for the expansion of workplace democracy, ought to be grasped, minutely examined for flaws, reshaped as necessary, polished, and put in place—and then watched very carefully.

QWL programs in the United States have taken many different forms and appeared in many different guises—participatory management, employee involvement, shop-floor democracy, consultation schemes, labor-management committees, quality circles, autonomous work groups, QWL teams, profit-sharing incentive structures, etc.

As a tool used toward labor's basic goals, these QWL programs can develop skill improvement programs, more flexible working schedules, greater job security and promotional opportunities, along with many other matters of great importance to the members we represent. So, other things being equal, unions have every reason to encourage and cooperate in any enterprise that will work to those constructive ends, for the benefit of workers and management alike.

But hard experience has taught us to look for pitfalls. Too many employers are more interested in programs that offer cosmetic changes that try to fool the workers into believing that management really cares about them, in spite of low pay and bad working conditions.

Too many union-busting "consultants" are promoting these QWL programs as an alternative to worker participation through trade unionism. That way, without the protection of a union contract, any concessions to workers can be revoked as easily as they were given. At best, the QWL group concept poses a problem to the labor movement because of the potential that exists for management to penetrate and influence small, informal work groups and bust unions.

For strong unions, able to insist on an equal and active voice in how the QWL program works and able, if necessary, to veto actions that aim at subverting its bargaining position, these are not insuperable problems. That accounts for the general acceptance of QWL programs by such dominant and secure unions as the Auto Workers, Steel Workers, and Communications Workers. Even they have sometimes had to take strong action to prevent their employers from using the programs for company propaganda in bargaining situations.

Other unions are in a more difficult posture. They have organized only a piece of the action—the other facilities of the same firm unorganized, under contract with another union, or a mixture of both. Here management more often controls the introduction and implementation of technology and QWL programs. Sometimes, in fact, they move ahead to new technology with major layoffs or plant closings with barely a nod to the union.

In doing so, they establish a carefully orchestrated organizational and communication link with the employees that can bypass or attempt to supplant the union. In part, this accounts for the more antagonistic response of unions which have only bits and parts of different firms and thus more limited bargaining leverage.

QWL programs, under whatever name, can be of tremendous help in facilitating the dealing with the larger issues of collective bargaining, including wages and working conditions and the job impact of new technology. At the same time, QWL programs can deal with other less visible but basic issues that affect the individual at the workplace.

Labor has no intention of allowing management to co-opt any of these basic issues. But dealing with QWL programs will present our unions with immense problems of educating our members—training and retraining of shop stewards and business agents; giving attention to the overall coordination of QWL programs plant by plant, employer by employer, and individual by individual; and developing at national staff levels the technical expertise to assist in the negotiation of QWL programs and in their development and maintenance; and resolving problems relating to sharing technology's benefits; and deciding what are necessary agreements and conditions before entering into QWL programs.

Every union must continue in every way possible to assert its rights and the rights of its members to acceptance as legitimate equals in a partnership with management, with collective bargaining as the essential foundation for labor-management cooperation.

We recognize the valuable contribution that properly constituted and equally balanced labor-management programs can make in fulfilling the American trade union member's desire for individual recognition, dignity, safety, quality of work life, and job security.

To that end, unions will cooperate with managements that recognize and support the right of workers freely to join unions of their choice and who demonstrate willingness to work with unions as equal partners in all areas that affect their members' interests, including the impact of technology.

But unions will reject, as a dangerous fraud, all efforts to use specious programs and rigged committees to undermine unions, divert attention from the real needs of workers, and weaken enforcement of the Nation's labor laws.

Conclusion

Workers and their unions have reasonable, understandable, and legitimate concerns about loss of jobs, loss of income, and loss of life and health. If these concerns are met adequately and effectively, workers will be much more willing to accept and adjust to changing technology.

There are no simple solutions to the task of protecting workers against the adverse impacts of changing technology. In thousands of labor-management contracts covering millions of workers in both the public and private sectors, unions and management have adopted a wide variety of provisions to cushion workers against these adverse impacts. These provisions fall into a few general categories—job protection, income protection, safety and health protection, retraining, and relocation assistance. The specifics include attrition or no-layoff protection, early warning of technological change, seniority protections, early retirement opportunities, "red circle" pay protection, shorter workweeks or work-years, relocation rights to follow transferred operations, severance pay, negotiated safety-health protections supplementing safety-health laws and regulations, and many other specific labor-management collectively bargained responses to technological change.

Without full collective bargaining—no matter how enlightened or benevolent management may be—working men and women simply don't have a sense of participation in the basic decisions which govern their jobs, their income and their lives. Collective bargaining is essential to help workers share the benefits of technological progress and help workers to meet the challenge of technological change with a minimum of social and human dislocation.

LABOR-MANAGEMENT RELATIONS IN AN ERA OF PROGRAMMABLE AUTOMATION

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Introduction

Currently we know very little about the impact of programmable automation on labor-management relations. One gets the general impression that the impact to date has been relatively small, except on a handful of occupations and industries. The potential for dramatic growth in the utilization of programmable automation, however, is generally acknowledged, albeit, the timing of rapid diffusion remains iffy. The potential for growth raises a number of important questions about labor-management adjustments during an era of programmable automation. First, we must ask: What shapes the decisions of employers to invest in programmable automation? Will unions impede the diffusion of programmable automation and to what degree (if any)? What impact will unions have on the lag between the introduction of commercially available programmable automation and its diffusion in manufacturing? Simultaneously, we must ask: What will be the degree of displacement of workers? What happens to displaced workers? What proportion will be retrained by employers? How many will be laid off? What kind of changes in work rules will unions seek? What kind of changes will unions gain? Will white-collar workers seek union representations?

Answers to these questions require in-depth research. Toward developing a research design, I begin with an overview of the current utilization of robotics in manufacturing and the extent of collective bargaining. I then discuss several collective bargaining issues relevant to an understanding of labor-management relations and the utilization of robotics. Subsequently, I lay out a research agenda, including a theoretical explanation of collective bargaining, implicit model specifications, and data collection.

Programmable Automation and Collective Bargaining in Manufacturing

Although programmable automation encompasses more than robotics, it is this form of programmable automation that most directly impacts on blue-collar work forces and, thus, existing union-management relations. From a research design perspective, worker displacement caused by the introduction of robots can be more precisely quantified than say, for example, displacement caused by the implementation of computer-aided design techniques. Furthermore, firms and plants utilizing robots can be identified.

Currently, robots are capable of performing tasks associated with a handful of occupations. According to the Robotics Institute of America (RIA), there were fewer than 5,000 robots in use in the United States in 1980. Table C-6 reports the estimated number of robots by broad occupational application (17).

The type of broad occupational categories most vulnerable to replacement by robot applications are heavily concentrated in the metalworking industries (1). Table C-7 lists the basic metalworking industries by 2-digit Standard Industrial Classification (SIC) code, the number of unions representing workers within an industry, and the estimated union membership by percentage category.

It can be seen readily that metalworking manufacturing is heavily unionized and by a fairly large number of different unions. Table C-8 identifies some of the national unions that have been active in organizing drives in metalworking industries during 1980.

Time restraints in preparing this report have not allowed me to investigate the scope of contractual agreements pertaining to programmable automation. However, using the Bureau of Labor Statistics' (BLS)

Table C-6.—Robot Usage and Identification of Applications, 1980

	Welding	Machine loading, unloading	Foundry	Painting/ finishing	Assembly	Other
Number of robots	1,500	850	840	540	100	600

Table C-7.—Identification of Metalworking Industries and Extent of Unionization

Industry	SIC	Number of unions	Percent in industry unionized
Primary metals	33	14	50-75
Fabricated metals	34	28	50-75
Machinery (except electrical)	35	16	25-50
Electrical/electronic equipment	36	14	50-75
Transportation equipment	37	16	75-100

SOURCE: Bureau of Labor Statistics, *Directory of National Unions and Employee Associations, 1975*, Bulletin 1937.

Table C-8.—Unions Representing Workers in Metalworking Manufacturing Industries[a]

1. Allied Industrial Workers of America (AIW)
2. Aluminum Workers International Union (AWU)
3. Automobile, Aerospace, and Agricultural Implement Workers of America (UAW)
4. Boilermakers, Iron Shipbuilders, Blacksmiths, Forgers, and Helpers; International Union (BBF)
5. Carpenters and Joiners of America; United Brotherhood of (CJA)
6. Chemical Workers Union; International (ICW)
7. Clothing and Textile Workers of America; Amalgamated (ACTW)
8. Communications Workers of America (CWA)
9. Electrical Workers; International Brotherhood of (IBEW)
10. Electrical, Radio, and Machine Workers of America; United (UE)
11. Electrical, Radio, and Machine Workers of America; International Union of (IUE)
12. Engineers; International Union of Operating (IUOE)
13. Furniture Workers of America; United (FW)
14. Iron Workers; International Association of Bridge Structural and Ornamental (BSOIW)
15. Laborers; international Union of (LIU)
16. Longshoremen's and Warehousemen's Union; International (ILWU)
17. Machinists and Aerospace Workers; International Association of (IAM)
18. Marine and Shipbuilding Workers of America; Industrial Union of (IUMSW)
19. Metal Polishers, Buffers, Platers, and Helpers; International Union (MPBP)
20. Molders and Allied Workers Union; International (IMAW)
21. Oil, Chemical, and Atomic Workers; International Union of (OCAW)
22. Painters and Allied Trades; International Union of (IUPAT)
23. Paperworkers; United International Union (UPI)
24. Plumbing and Pipe Fitting Industry; United Association of Journeymen and Apprentices (PPF)
25. Service Employees; International Union (SEIU)
26. Sheet Metal Workers' International Association (SMW)
27. Steelworkers of America; United (USA)
28. Teamsters, Chauffeurs, Warehousemen, and Helpers of America; International Brotherhood (TCWH)

[a] The above list of unions was taken from NLRB union election files. The unions (and others) were involved in union representation elections in 1980 in the metalworking industries (SIC 33-38).

data base on union contracts *(Characteristics of Major Collective Bargaining Agreements)*, an examination of recent contracts negotiated by unions in manufacturing would reveal how unions alter the scope of collective bargaining as programmable automation becomes more widely applied.

A glimpse at contracts and various publications of the UAW, the USW, the IUE, and the IAM indicate that joint union-management committees have been established to address the general issue of productivity and the specific issue of technological change. A central purpose of these committees is to address in advance impending technological change: how to prepare for changes in the production process and how to mitigate its impact on the work force. Below I discuss the set of alternatives that unions and employers are likely to consider. One can only imagine that the scope of contractual agreements will change as more workplaces apply programmable automation to the production process. I propose below that we examine these contracts and the undertakings of joint union-management committees in order to understand more fully how labor-management relations cope with the application of programmable automation.

Current Collective Bargaining: Relevant Issues

In the following section I discuss several issues that are especially relevant to understanding union-management relations. My intention is to describe briefly some important parameters that help set the stage for my subsequent discussion of collective bargaining in an era of programmable automation.

Concession Bargaining

The current mood and trend in collective bargaining in manufacturing differs substantially from the past. Due to a deep recession and growing international competition, unions and employers have begun making concessions in wages, benefits, and work rules. Concessions by unions have covered wage and benefit packages and, to some degree, restrictive work practices. Concession bargaining is being witnessed in many places of employment—well beyond the highly publicized automobile, agricultural implement, rubber, electronic machinery, and ongoing steel negotiations. A recent mid-May poll by Louis Harris & Associates of 600 large corporations found that 26 percent of the unionized firms had obtained wage and benefit concessions in recent negotiations (4).

Employers, likewise, have had to make concessions—albeit types of concessions that do not lend themselves to easy pecuniary estimation. These concessions have included more union and worker input into management decisions and a variety of security provisions (e.g., added SUBs and reversals or postponement of plant closure decisions).

Several points can be made about the current concession bargaining. First, the recession itself would not have precipitated these concessions. The recession merely brought the longrun ills of some major industries to a head. The surge of foreign competition is the cause of the ongoing decline in much of U.S. manufacturing. Consequently, collective bargaining is beginning to address the long-term livelihood of many industries.

Second, concessions are being made by both unions and employers. This suggests that unions in these manufacturing industries are not ipso facto in weaker bargaining positions than employers. Instead, the industry is in a state of demise and, consequently, both employers and unions need to change standard operating procedures.

Third, job security has become the major bargaining chip. Rank and file have insisted on additional forms of job security (or monetary cushions to displacement) as the quid pro quo for concessions. Job security issues will continue to hold the limelight in further bargaining—primarily due to the longrun impact on existing employment in manufacturing; both in the potential reduction of existing jobs and in requiring major changes in the structure of work.

Programmable automation, therefore, will be viewed by labor much like foreign competition is viewed—as a threat to longrun employment. Job security, in turn, will be the bargaining chip for cooperation with management in restructuring hard-hit industries. In order to maximize the utilization of programmable automation, unionized employers will have to higgle and haggle over job security provisions.

Legal Requirements of Collective Bargaining and the Issue of Programmable Automation

Union-management relations have been shaped substantially by the National Labor Relations Act (NLRA) and any departure from the legal duty to bargain in good faith is highly unlikely. The National Labor Relations Board (NLRB) is the regulatory agency charged with the interpretation (along with the courts) and application of NLRA. It has laid down the ground rules (albeit foggy ones at times) to protect both parties from unfair labor practices.

In particular, the NLRB has attempted to delineate mandatory bargaining subjects (i.e., the subjects and issues for which the parties must negotiate in good faith). Good faith bargaining requires discussion but not necessarily concession to either party's demands. However, the NLRB generally has interpreted the lack of compromise as evidence of bad faith bargaining. Mandatory subjects fall under the heading of wages, hours, and other terms and conditions of employment. Ever since the landmark Supreme Court case of *Fibreboard Paper Products* v. *NLRB* (1964), the NLRB has interpreted such issues as subcontracting and plant closures as mandatory bargaining subjects. Until 1972 (Summit Tool Co. Case), employers had the legal responsibility to negotiate in good faith about decisions to subcontract (where such subcontracted work was previously done by current employees) and close plants. The Summit Tool Co. Case appears to allow employers to make unilateral decisions to close plants but still requires employers to negotiate in good faith about the displacement effects of plant closures.

The question to raise is, what will the NLRB require in terms of good faith bargaining when workers face displacement by programmable automation? It appears that if employers close plants and resort to subcontracting previous in-house production, they will be obligated to negotiate with unions—at least about the impact of these decisions on labor. It is difficult to second-guess the NLRB since: 1) it is not clear to what extent employers will close plants and/or subcontract, 2) the complexity of cases leads to unclear precedent and, thus, case-by-case resolution, and 3) the changing make-up of the Board leads to inconsistency in the interpretation of unfair labor practices (10).

Although it is unclear what impact the NLRB will have in resolving disputes over programmable automation, it is clear that NLRB governance of labor-management relations will help shape labor-management relations affected by programmable automation. It is also clear (given the enormous workload of the NLRB) that the typical long delay in NLRB conflict resolution will add to the transitory problems we might anticipate as we move into an era of programmable automation.

Union Organizing Activity

Table C-9 provides a description of union election activity since 1950. Column 1 shows that the percent of workers unionized in the nonagricultural labor force has declined steadily since 1955—from a high of 33 percent to the present low of approximately 24 percent. Part of this decline is attributable to a long-term drop in union success in representation elections; from a high of winning 75 percent of elections in 1950 to the current low of winning only 46 percent of elections. Concurrent with increased election losses has been a substantial drop in the average size of work units holding elections; from 519 workers in 1950 to only

Table C-9.—Annual Observations on Selected Parameters of Union Representation Elections

Year	(1) Percent of the nonagricultural labor force unionized[a]	(2) Percent of elections won[b]	(3) Average unit size[b]	(4) Percent manufacturing[a]	(5) Percent consent[b]
1950	31.5	74.5	158.5	39.0	(c)
1955	33.0	65.3	122.4	38.6	42.6
1960	31.5	58.6	75.9	36.6	42.2
1965	28.5	60.2	70.0	35.6	46.9
1970	27.3	55.2	75.4	33.2	26.5
1971	27.0	53.2	70.1	31.8	23.1
1972	26.4	53.6	66.3	31.6	20.2
1973	25.9	51.1	57.8	31.8	16.3
1974	25.8	50.0	61.5	31.2	14.7
1975	25.3	48.2	66.3	29.4	11.6
1976	24.5	48.1	55.0	29.4	10.4
1977	24.1	46.0	60.2	29.2	8.9
1978	24.0	46.0	57.3	29.2	7.9

[a] Data are for calendar years.
[b] Data are for fiscal years.
[c] No comparable figure available for 1950.

SOURCES: Columns 2, 3, and 5 are taken from various annual reports of the NLRB. Column 4 is adopted from the 1979 *Handbook of Labor Statistics*. Column 1 is adopted from the *Directory of National Unions and Employee Associations, 1979*.

57 workers in 1978. Obviously, this has had a substantial affect on total union membership. Column 4 presents the percent of workers employed in manufacturing. The loss in manufacturing employment is widely cited as a leading cause in the decline of union membership, primarily because manufacturing has been a historic stronghold for the union movement. A recent study of union elections over the 1970-78 period shows that roughly 28 percent of all private sector elections were held in manufacturing industries and that, on average, workers were more likely to vote against union representation (all other things held constant) than their counterparts in nonmanufacturing industries (19).

Stepped-up employer resistance, however, has perhaps had the greatest impact on union representation elections. Employers, for example, rarely consent to union elections today. Instead, employers have been campaigning actively against union representation. For instance, using the percent of elections consented to by employers, column 5 shows that consent elections have dropped dramatically from a high of 47 percent in 1965 to under 8 percent by 1978. Recent studies find a large negative and highly significant relationship between not consenting to elections and those election outcomes (9,19).

Another area of interest is white-collar unionization. Chamberlain, et al. (7), report that as of 1976, roughly 18 percent of the membership in national unions was white-collar (professional-technical, clerical, and sales workers). That figure represents an increase in white-collar unionization in recent years. For instance, in 1960 only 12 percent of national union membership was white-collar. This reflects an increase from 2,200,000 union members in 1960 to 3,850,000 in 1976. If membership in employee associations is added to union membership, the proportion of members from white-collar occupations becomes 27 percent. Cooke (9) also finds in an analysis of private sector elections in 1979 that both professional-technical and clerical-sales work groups were much more likely to vote for union representation than blue-collar workers voting in representation elections. However, it should also be noted that only 13 percent of 1979 elections involved primarily white-collar work groups.

Several important points can be drawn from the above discussion. First, the union movement in the private sector has been experiencing a long-term decline in its relative power—at least as proxied by membership figures. Second, the relative bargaining power in manufacturing has experienced the greatest slippage. Third, employer resistance to further union organizing has increased dramatically over the last 15 years. Finally, white-collar unionization has been increasing and remains a potential growth area for the union movement.

Collective Bargaining in an Era of Programmable Automation: A Research Agenda

Absent one of those funny little crystal balls, the task of anticipating the impact of programmable automation on labor-management relations will require more in-depth and sophisticated research than is currently available. In the following section I sketch out a general theory of collective bargaining. I then raise a set of questions about the impact of union-management relations. Subsequently, I develop a set of implicit models to answer these questions. Finally, I discuss data collection issues and propose a research plan.

A General Theory of Collective Bargaining

Dunlop (11) advocates the use of a systems framework in the general analysis of union-management relationships. His framework encompasses three broadly defined actors: 1) workers and their representatives, 2) management, and 3) interested government agencies (the NLRB for present purpose). These actors interact within a set of environmental constraints (technological, economic, and sociopolitical) to establish the rules of the work relationship; both pecuniary and nonpecuniary. Although Dunlop's framework is based on a historically observed set of relationships, he fails to breathe any life into the framework. A suitable theory, however, requires some underlying motivator(s) that helps explain and predict behavior. My general intention here is to utilize Dunlop's set of actors, but make them dynamic and explain their interaction within the environmental context.

Theoretical analyses of negotiations are based on the conceptual idea that bargaining "power" determines the outcome(s) of negotiations or, more generally, union-management relations. Concerned primarily with the ability of unions to raise wages, Pigou and Hicks (16,13) define bargaining power as the ability of unions to increase wages above competitive wage levels. This concept of bargaining power has become popularly known among economists as the union's "monopoly power" to raise wages (20). Chamberlain and Kuhn (8) suggest a broader definition of power that encompasses more than wage gains: power is the ability to secure some agreement that otherwise would not be granted. This latter definition is more appropriate for our present purpose. In the simplest context, unions (employers) use power to force employees (unions) to agree to sets of work rules.

Since power is primarily the *means* of attaining some underlying goal(s), one needs to examine more closely the central goals of the parties. It would seem reasonable to believe that unions, employers, and government agencies act under some premise of utility maximization. Although utility maximization offers an underlying motivator (i.e., maximizing behavior), it does not lead us to what actually motivates parties; except "whatever motivates the parties" (i.e., utility). Unless the researcher assumes what utility represents (e.g., profits, wages, etc.), the researcher cannot model very well any cause-effect relationships. Since the analysis of industrial relations issues encompasses economic, sociological, political, and psychological relationships, we need to establish a motivating principle which is amenable to incorporating such a complex array of factors.

I argue here that unions, employers, and the NLRB attempt to "optimize control" over employment relations. For unions (acting as the voice of workers), optimization of control over employment relations includes, for example, increasing job security and minimizing employer discretion with respect to wages and benefits, work assignments, displacement, and worker discipline. Optimization of control, however, does not mean that unions want complete responsibility for managing employment relations. Instead, unions want to maximize control up to the point where their members' employment prospects are not jeopardized through massive layoffs or business closures. In contrast to union optimization of control, employers want near unilateral control of all decisions affecting employment relations. Obviously, unionized employers have given up substantial control of the work rules. The optimization thesis holds that unions and employers are motivated to wrestle back as much control as possible; which implies that any state of equilibrium is short-lived. Such an optimization principle, therefore, places unions and employers in a natural state of conflict (although not necessarily in a destructive one).

During negotiations both unions and employers draw on their respective bargaining power to wrestle control from one another. Under the thesis that bargaining power determines negotiation outcomes, the sources of bargaining power must be examined. But first, bargaining power should be defined in relative terms since union and employer willingness to use potential power is a function of the perceived net gain (i.e., total benefit minus total cost) associated with using that potential power. For instance, a union's willingness to endure a strike to force an employer to agree to a change in a contract is dependent on the perceived net gain to the union of such a strike. Likewise, an employer's willingness to take a strike to avert signing the change in contract is dependent on the perceived net gain associated with taking a strike. In defining relative power, Chamberlain, Cullen, and Lewis (7) argue that:

> Only if the cost to management of not agreeing to the union's terms exceeds the cost of agreeing with them, and if the cost to the union of not agreeing to management's terms is less than the cost of agreeing to them, does the union's bargaining power surpass that of the management.

Such a definition of relative power is dependent on the size of the demand, however. For example, if a union's demand is for a 30-percent increase in "costs" to the employer, the union's relative power is less than if the demand is only 10 percent. This implies that unions and employers will be more successful in negotiating contract changes as the cost of change becomes smaller.

The sources of relative power are determined by an array of economic, technical, legal, organizational, and sociopolitical factors. As any factor changes (or differs across firms), the relative bargaining power changes (or differs across firms). The set of implicit models described below are derived by focusing on parameters of the various sources of relative power. This set of structural equations is designed to provide answers to some basic questions about union-management relationships in an era of programmable automation.

Model Specification: Implicit Models

At this stage of the analysis I formulate several implicit models; models that begin to establish the conceptual understanding of cause-effect relationships between the diffusion of programmable automation and union-management relations. Explicit empirical specifications detailing functional form and variable measurement will require considerable additional effort.

Based on a theory of control optimization, any change in the work rules attributable to programmable automation will be a function of the employer's bargaining power vis a vis the union's bargaining power. Stated algebraically,

$$\text{Work Rules} = f\ (POW_m/POW_u)$$

where POW_m = power of management and POW_u = power of union. As discussed above, the relative power of the parties depends on the sources of power and the perceived cost of the change in work rules. Thus,

$$POW_m/POW_u = f\ (\text{sources of power} + \text{cost of change})$$

The utilization or diffusion of programmable automation (which can be viewed as a change in work rules), therefore, becomes a function of relative power:

$$\text{Diffusion} = f\ (POW_m/POW_u)$$

Similarly, a union's response to the utilization of programmable automation is a function of relative power:

$$\text{Union Resp.} = f\ (POW_m/POW_u)$$

Several of the questions raised in the introduction basically ask: how will unions influence the diffusion of programmable automation? In effect, we want to test the hypothesis that a union's response influences diffusion. The dependent variable, therefore, is the diffusion of programmable automation. Diffusion can be evaluated as: 1) the decision to invest, or 2) some measure of the amount of utilization (e.g., number of robots), and/or 3) the lag in diffusion. The dependent variable can be evaluated at firm or industrywide levels.

Our theory implies that the diffusion of programmable automation increases as the relative power of management rises above the relative power of the union, and conversely. Since relative power is a function of the perceived cost of the change of work rules plus sources of power, relative power varies as the cost of the pending change varies and as the parameters of the sources of power vary. Consequently, our analysis focuses on the cost of proposed changes in work rules as well as the parameters of sources of power.

We can begin by postulating that the diffusion of programmable automation is a function of: 1) the union response to proposed or anticipated utilization of programmable automation, plus 2) a vector (X) of other variables.

$$\text{Diffusion} = f\ (\text{union response}, X)$$

Our theory says that the union response will be a function of the cost of proposed changes and its source of power.

$$\text{Union Resp.} = f\ (\text{cost of changes} + \text{sources of power})$$

Thus, everything else constant, as the cost to a union of the application of programmable automation increases, the more negative the response of the union. As discussed in the section about concession bargaining, job security becomes the central issue and the primary bargaining chip in negotiations. At the extreme, for example, if displaced workers are laid off (and say without severance or relocation pay), the cost to the union in membership and status is quite high. Of course, the greater such layoffs, the greater the cost to the union. Under these circumstances the union response will be strongly negative to the diffusion of programmable automation. At the other extreme, where, for example, all displaced workers are retrained or placed in alternative and equivalent jobs, the cost to the union is negligible: causing no negative response by the union (except perhaps to seek the establishment of a joint union-management committee to prepare for future diffusion).

Under the negative response scenario, (and again, everything else constant) the union will attempt to negotiate work rules protecting its membership. Thus, the union will attempt to increase the cost to the employer of making changes in working rules. One can imagine a wide range of proposals at the bargaining table, including: 1) guarantees of employment (perhaps tied to years of seniority); 2) restrictions on timing of the implementation of programmable automation (e.g., implementation would be tied to normal work force attrition or requirements of advanced notice); 3) retraining requirements; 4) postponement of plant closures and subcontracting; 5) cushions to layoffs (e.g., severance, relocation, or SUB payments, and early retirement schemes); 6) reduction in work hours; and 7) union shop requirements covering newly created jobs.

Holding constant the cost of management's proposed changes in work rules, we can now consider the sources of power that determine the union's ability to negotiate protective work rules. It is hypothesized that the greater the union's power, the more successful it will be in negotiating protective work rules, and the more costly it becomes for management to change work rules (i.e., utilize programmable automation).

Sources of power are gained or lost according to variation in the economic and technological context of the firm, union organizational strength, legal constraints, and the sociopolitical environment. With respect to the economic context, the power of the union varies with: 1) labor costs (e.g., wages, labor cost per unit produced, wage bill/total cost, etc.); 2) the product market (profits, sales, industry concentration, insulation from foreign competition, etc.); and 3) the labor market (employment growth in firm or industry, layoffs, unemployment, etc.) As an illustration, in a firm or industry experiencing a loss in sales, declining profits and employment, and a growing threat from international competition, the union's sources of power are diminished as well as its ability to shift the cost of work rules to the employer.

With respect to the technological context, the more the production process is amenable to the utilization of programmable automation and/or the less strategic the work force in the production process, the less the power available to the union. This relationship is analogous, in part, to the study of union strike activity, whereby union strike activity is reduced as the production process can be manned temporarily by nonunion supervisors and workers.

Everything else constant, organizational strength plays a role in determining the union's strength. Worker unity in supporting leadership initiatives, the willingness of workers to endure strikes, the financial resources of the union, membership size and extent of organization, and negotiation skills are all positively related to union power.

The NLRB also plays a potential role in shaping the union's power. The impact of plant closures and subcontracting on the work force, for example, are mandatory bargaining issues. If the NLRB interprets its current legal precedent about displacement to also include displacement caused by the introduction of programmable automation, then the union's power to negotiate protective work rules is enhanced.

Finally, both employers and unions are sensitive to the sociopolitical climate. If public opinion supports notions of "job rights" and "employer responsibility" for displacement, then unions will draw on this support in negotiating with firms. Sociopolitical support for union initiatives will depend in large part on the impact of displacement on a given community. Communities have played, for instance, an active role in keeping some plants open.

In summary, the impact of unions on the diffusion of programmable automation depends on the cost to the union of its implementation and union sources of power. Likewise, the diffusion of programmable automation depends on the power of the employer (which is a function of the cost to the employer of changes in the work rules and the employer's sources of power). The cost to the employer of utilizing programmable automation can be treated as a standard investment decision. The rate of return is obviously reduced as unions are able to increase the cost of utilization (i.e., more expensive work rules). The ability of employers to keep the investment cost down is a function of their power sources. The sources of power are determined from the same set of economic, technological, organizational, legal, and sociopolitical parameters that determines the power of the union. Parameters that yield power to the union generally take power away from the employer, and conversely. Through negotiations over work rules, the parties will eventually sign a contract that generally reflects compromises by both, and which theoretically reflect the relative power of the parties.

The types of renegotiated work rules will also reflect the preferences of the parties. For example, unions and employers may be willing to trade regular wages and fringes for greater security provisions like retraining and relocation pay, since job security becomes a primary concern. The types of outcomes, for labor, therefore, are tied to relative bargaining power and preferences of the parties. One can imagine a wide variation in outcomes among unionized firms.

It seems reasonably clear that as the capabilities of programmable automation increase and as the price per unit drops, there will be a substantial impact on unionized workers in selected occupations, industries, and localities. It would not be feasible for employers to retrain substantial portions of their work forces. Consequently, unions will attempt to bargain work rules that cushion the layoff experience of large numbers of workers. It also seems reasonably evident that as the diffusion of programmable automation progresses rapidly in nonunionized establishments, the longrun threat to unionized groups of losses in employment due to noncompetitive work rules will diminish the sources of power for unions. As such, it becomes less likely that unionized employers will agree to protective work rules.

Finally, let me briefly address the issue of union organizing activity of white-collar workers. First, the diffusion of programmable automation (especially in the form of computer-aided design and manufacturing) also threatens existing white-collar jobs. The desire for job security and due process are important factors in work group decisions to unionize. As noted in the section "Union Organizing Activity," white-collar unionization has been increasing and remains a potential growth area for the union movement. Second, unions which can organize both blue- and white-collar workers, obviously increase their sources of bargaining power to negotiate protective work rules. Thus, in firms and industries with the greatest potential for white-collar displacement by programmable automation, the likelihood that white-collar work groups will unionize increases. One can note, for example, that white-collar workers at General Motors very recently have shown considerable interest in attaining UAW representation primarily, it appears, because of declining job security.

Data Analysis and Research Plan

Our knowledge of the relationship between the diffusion of programmable automation and labor-management relations is very limited. We simply have no adequate empirical information to make reliable judgments about the impact of unions on the diffusion of programmable automation, nor the impact of programmable automation on union-management relationships and worker displacement. In part this can be attributed to the modest and welcomed encroachment of programmable automation to date. However, if the type of projections of programmable automation utilization made by RIA are reasonably accurate (a threefold increase for 1985 over 1980, and twentyfold increase by 1990), the need to increase our knowledge on this subject is highly warranted.

I suggest that we examine existing evidence in light of the implicit models described above. The first step would be to formulate a set of tentative explicit empirical models derived from the above implicit modeling. Once the critical (and measurable) variables are identified and the models are written in appropriate functional form, we can begin efforts to obtain the necessary observations to test the models.

The information we seek covers: 1) the extent of utilization and how employers weigh the reaction of unions and/or workers in making investment decisions; 2) the negotiation experience (i.e., the changes in work rules); 3) the parameters of the sources of power for employers and unions; and 4) the impact on the work force (e.g., numbers of workers retrained, relocated, or laid off, etc.) Toward this end we need the cooperation of employers and unions. Unfortunately it is not clear at this point how much cooperation we will receive. The second step, therefore, calls for a limited exploratory effort to test the waters. In testing the waters, we can make a judgment of the likelihood of successfully gathering the necessary data. Furthermore, we will learn: 1) what data on the variables in the tentative explicit models can be collected, and 2) what additional parameters should be considered in our hypothesis testing.

If the second step indicates that further data collection is feasible, then as a third step we need to identify the users of programmable automation; and ideally, potential users. Given that in 1980 there were about 5,000 robots installed, we have a fairly large population of programmable automation applications. RIA is probably the best source of information on users and potential users in manufacturing. After identifying the population of users and potential users, we can then begin the process of selecting a representative sample. A small population of users, however, would allow us to examine the entire population.

Finally, once the data have been collected, the explicit equations can be estimated. Only at that point should inferences be drawn, projections made, and policy scenarios evaluated.

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